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MILITARY PREVENTIVE MEDICINE

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BY

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THIRD EDITION

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FOREWORD

The health of military commands is certainly one of the first matters to be considered in the development of military forces and continues to be of the first importance in active military operations. History is replete with instances of failure of campaigns because of loss of manpower by disease, chiefly epidemic in character.

The principles underlying preventive medicine are well understood and the result of their application in the home and in civil communities constitutes one of the great achievements of the past half century in the cause of human welfare. But these results have been brought about largely by practical means and methods, such as water purification, pasteurization of milk, control of other food supplies, waste disposal, immunization, and many other administrative measures constituting collectively public health administration.

The military environment shapes the policies of practical sanitation. Measures applicable in the home or in civil communities are often found impracticable in the military service. Knowledge of these conditions is essential in determining just what sanitary projects are practicable in the army and how to proceed to obtain the best results. These difficulties, however, are overbalanced by the favorable opportunities afforded by the military service for the practice of preventive medicine and sanitation. These measures in time of war can be applied with the full force of governmental authority and results recorded in groups of millions. Some of medicine's greatest contributions have been brought about in war time, when organization and authority to act have been granted the medical service.

Assuming, therefore, that the principles of preventive medicine from the standpoint of pure science are well understood, that disease is one of the deadliest enemies attending the concentration of men from diverse sections of the country, and that military authority greatly facilitates the practice of preventive medicine, it is evident that the remaining requirement for the success of the medical service of armies is a knowledge of the military environment to which the principles of preventive medicine must be adjusted in a practical way. This book on military preventive medicine defines these principles and the opportunities, limitations, and responsibility of medical officers in applying them. The most valuable contributions of the Medical Department of the Army have been in the field of preventive medicine. The dividends from intelligent service in the future will be no less.

I know that the previous editions of this book, as written by General Dunham, have been of great service to staff officers and troop commanders as well as to Medical Department officers. It is more than a compend; it is a practical reference text on military preventive medicine and practical sanitation. In this, the third edition, the general subject matter has been rearranged, more and better illustrations have been included, and additions have been made in keeping with the advancement of medicine in its relation to prevention.

C. R. REYNOLDS,
Major General, U. S. Army,
The Surgeon General.

PREFACE TO THIRD EDITION

The purpose of this work is stated in the preface to the first edition. In the preparation of the third edition, the entire text has been revised and, as nearly as practicable, brought up to date. Subject matter dealing with the numerous advances that have been made in the practice of preventive medicine since the publication of the second edition has been included in the third edition, and obsolete material has been deleted. In order to clarify the text, a number of new illustrations have been added.

I am indebted to many friends who gave me very helpful comments and suggestions which I have used freely in the preparation of the third edition. I wish particularly to acknowledge the assistance of Lieutenant-Colonel W. A. Hardenbergh, Sanitary Corps Reserve, Lieutenant-Colonel George F. Lull, Medical Corps, Lieutenant-Colonel John W. Meehan, Medical Corps, Lieutenant-Colonel A. P. Hitchens, Medical Corps, Lieutenant-Colonel J. P. Crawford, Medical Corps, Lieutenant-Colonel F. H. K. Reynolds, Veterinary Corps, Captain A. T. Thompson, Veterinary Corps, and Captain W. S. Stone, Medical Corps, each of whom read and criticized various parts of the text.

I am also deeply indebted to Major General Charles R. Reynolds, Surgeon General, U. S. Army, Colonel J. F. Siler, Medical Corps, Director of the Army Medical School, and Colonel H. C. Gibner, Medical Corps, Commandant of the Medical Field Service School, for making facilities available for the preparation and publication of the third edition.

I especially wish to express my sincere appreciation of the efficient service rendered by Staff Sergeant J. E. Rice, Medical Department, U. S. Army, in supervising all the clerical work connected with the preparation of this edition.

GEORGE C. DUNHAM.

Army Medical School,
Army Medical Center,
Washington, D. C.
June 30, 1938.

PREFACE TO FIRST EDITION

This text has been prepared for the purpose of incorporating under one cover the major portion of the basic information essential to the practice of preventive medicine in the army. The objective sought is to provide Medical Department officers with a source of information which will assist them to determine by inspections and studies the effect of existing conditions on health and to formulate and supervise the application of measures which will protect and promote the health of troops. With this objective in view, special attention has been given to those epidemiological factors which are directly concerned in the control of communicable diseases among troops, and to environmental conditions which influence or facilitate the spread of disease. The epidemiology of communicable diseases is considered chiefly with regard to the application of practical control measures. Water purification, food control, waste disposal, insect control and housing procedures are discussed from the viewpoint of the inspector who must make recommendations for the correction of defects and deficiencies.

No attempt has been made to cover the entire field of preventive medicine. Every effort has been made to avoid controversial points and to include only facts and accepted theories. The literature on each subject has been freely consulted, but, as the text is intended to serve mainly as a field manual, it has not been deemed necessary to include a bibliography or references to literature.

I wish to acknowledge the assistance of many friends, particularly members of the faculty of the Medical Field Service School, who read and criticized all or parts of the text. I also desire to acknowledge my indebtedness to the many authors from whose works I obtained information. I am especially indebted to Colonel Charles R. Reynolds, Medical Corps, U. S. A., Commandant, Medical Field Service School, who not only reviewed and criticized the entire text, but also

made facilities available without which this work could not have been accomplished. I particularly desire to express my appreciation of the valuable assistance rendered by Captain Harvey I. Rice, Medical Administrative Corps, who supervised all the work connected with the printing of this book.

GEORGE C. DUNHAM.

Medical Field Service School,
Carlisle Barracks, Pennsylvania,
June 30, 1930.

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CHAPTER I.

INTRODUCTION

The objectives of military preventive medicine are the prevention or control of disease among the members of military forces and the maintenance and conservation of the health and physical fitness of troops. Military preventive medicine is analogous to the public health activities of civilian communities, except in so far as it is modified in scope by military conditions. These modifying conditions are mainly those resulting from characteristics peculiar to a military population, environmental factors which accompany military activities and the restrictions imposed on the practice of preventive medicine by the nature of the military mission.

A military organization is composed of a highly selected portion of the general population of the country. With the exception of members of the Army Nurse Corps, the personnel consists entirely of adult males, and the greater proportion of the enlisted men are in the 20 to 30 year age group. At stations and, in some instances, in permanent camps, the character of the population under military jurisdiction may be modified by the presence of the families of the officers and men and by female civilian employees, but their numbers are seldom sufficient to exert any great influence on the prevalence of disease in the military community. Military preventive medicine does not, therefore, include within its scope such

public health activities as child or maternal hygiene or school sanitation.

All members of a military organization are subjected to a thorough physical examination before being commissioned or enlisted, and only those who can meet certain physical standards are accepted. A population selected by this process has a higher group resistance to many diseases than the general population, and responds more readily and to a greater degree to measures designed to increase physical fitness and promote general health. The selection of military personnel by physical examination is a phase of military preventive medicine and in the practice of preventive medicine in the army cognizance must be taken of the characteristics conferred on the military population by such a method of selection.

Military establishments differ mostly from civilian communities in the nature of their environmental conditions, especially with respect to crowding and close contact between individuals. Military activities, regardless of whether these consist of training in station or camp or of operations in the field, are accomplished by groups and masses of individuals organized into units. The members of a basic military unit, as represented by the company, are housed and fed as a group. They are drilled and are otherwise trained as a group. They march and go through combat as a group. There is, therefore, inevitable close contact between individuals, with concomitant opportunities for the transference of disease producing organisms.

When troops move into the field away from established camps or stations, whether for training purposes in peace or war or to meet an enemy, they are necessarily subjected to primitive environmental conditions. Under these conditions, water must be obtained from any sources which are locally available, food must be prepared and served in the open, canvas or improvised shelter must be utilized, wastes must be disposed of wherever produced, and exposure to the elements, and, in some instances, to the bites of disease bearing insects, is increased.

The mission of a military organization is of paramount importance and must be considered in the formulation and execution of measures to protect the health of the command.

For example, with troops in training for combat, health measures which do not expedite such training, or which interfere with training more than the conditions they are designed to correct, are neither feasible nor practicable. In combat, many sanitary procedures which are necessary and practicable under other circumstances, cannot be employed because they would interfere too much with the accomplishment of the military mission of the command.

On the other hand, however, many health measures can be much more fully and effectively enforced under military conditions than in a civilian community. Military training and military discipline, when supported by adequate inspection and official supervision, render it possible and practicable to employ to its full value any sound health measure. For example, transmission of disease by food can be prevented by control of the messes where the troops are fed; and trained, well disciplined troops can be prevented from eating food at places other than the designated messes. Or every member of a command may be artifically immunized against a disease when deemed necessary by proper military authority. Further, any member of a military organization may be physically examined at any time to determine conditions inimical to his own health or which would be a menace to others. As a result of these factors, wherever practical measures for the control of a disease are available, that disease tends to be less prevalent in a military force than among similar population groups in a civilian community. This is true of such diseases as typhoid fever, smallpox or malaria. On the contrary, the incidence of such diseases as measles and mumps, against which no specific or generally effective control measures are available, tends to be higher in the military service than among the members of the corresponding population group of a civilian community.

THE ROLE OF MILITARY PREVENTIVE MEDICINE

In a military force, the crowding and the consequent close contact between individuals, as well as the primitive environmental conditions under which troops must live in the field, are all conducive to the spread of epidemic diseases. Prior to the advent of modern preventive medicine, that is, before

the beginning of the twentieth century, the concentration of any considerable number of troops, especially recruits, was in most instances accompanied by the occurrence of epidemics. In many campaigns, disease prevented the full achievement of the military mission and even led to defeat. In all armies the intestinal diseases, such as typhoid fever and dysentery, raged practically unchecked and where conditions were favorable, such diseases as typhus, malaria or plague wrought havoc among troops.

Today, preventive medicine provides means for the control of many of the diseases that formerly were prone to occur in epidemic form whenever and wherever an army was mobilized. The incidence of intestinal diseases can be reduced to negligible proportions by environmental sanitation and immunization. Insect-borne diseases can be practically eliminated from a command by the application of known insect control measures. Vaccination will prevent smallpox. Chemical prophylaxis affords a method of checking the incidence of venereal disease. In fact, the only important epidemic diseases for which no adequate control measures are available at the present time are certain of the respiratory infections.

The methods by which troops must be mobilized for modern warfare create conditions which are ideal for the spread of epidemic diseases. Young men are brought together in large numbers directly from civil life. They come from many sections of the country and bring with them the diseases prevalent in the various sections. Transportation facilities are such that men can be transported from their homes in any section of the country to a camp or area in any part of the nation within the incubation period of many of the epidemic diseases. Any command which is being mobilized will, therefore, receive early and missed cases and carriers of disease. These serve as foci from which disease will spread to the susceptible members of the command unless adequate control measures are instituted.

Regardless of the plan of mobilization employed, men who are to be given military training must be grouped and the crowding incident to such grouping facilitates the transmission of disease. While the group susceptibility of a newly mobilized unit will vary according to the previous experience of its members with infectious diseases, any body of recruits

is, as a group, relatively much more susceptible to disease than a trained unit.

As time goes on members of the military age group are becoming more and more susceptible to many of the common communicable diseases. Owing to the increasing degree of protection from disease afforded the children of the country, greater numbers are reaching adult life without having become immune, or with a low resistance to certain of the common infectious diseases. It can, therefore, be reasonably expected that troops mobilized in the future will have a higher group susceptibility, not only to those diseases against which one attack confers immunity, but also to those against which resistance is developed by repeated exposures to infections or by repeated attacks.

As newly mobilized troops have a relatively high group susceptibility to the common infectious diseases and as sources of infection are sure to be present, epidemics can be prevented only by the employment of suitable control measures. The control of disease is, therefore, an exceedingly important phase of mobilization. Any break in the protective barrier against disease occasioned by the absence or inadequacy of control measures will result in the occurrence of epidemics. Under the military system employed by the United States, speed will always be an essential factor in the training of troops for war. If epidemic diseases prevail among troops in training, the progress of the training will be seriously impeded with possibly disastrous results to the nation.

Where an epidemic disease occurs among troops engaged in combat or among those being concentrated preparatory to combat, it may seriously interfere with military operations. In these situations disease causes not only an actual loss of valuable manpower, but military movements are hampered by the presence of the sick, the hospital facilities required for the care of wounded are crowded with sick, and the presence of epidemic disease has a depressing effect on the morale of troops.

The control of disease in peace time garrisons differs in no essential respect from public health work in a civilian community, except in so far as the problems presented are modified by the character of the population and the nature of the military environment. With regard to the spread of disease,

the military station in peace time is an inherent part of the surrounding civilian community. Diseases prevailing among the inhabitants of surrounding civilian territory will, unless prevented, spread among the troops of the station and *vice versa*. This means that not only is the disease situation within a command important, but cognizance must also be taken of the diseases occurring in nearby civilian communities.

Epidemic diseases, as they occur in a military organization, are of military importance only in so far as they interfere with the attainment of the military mission of the command and, therefore, the principal purpose of disease control in the army is to keep as many men as possible physically fit for duty. In other words, the importance of a disease and the value of disease control procedures are determined by their influence on the noneffective rate rather than by their effect on morbidity or mortality rates. Thus, a disease which, because of its high fatality rate or disabling sequelae may be of great importance in a civilian community or to the individual concerned, may have but little influence on the noneffective rate of a military force. On the other hand, diseases which are not fatal or have only a low fatality rate, but which render large numbers of men noneffective or reduce the effectiveness of the command as a whole for training or for combat, exert the greatest effect on the efficiency of a military force or on military operations. For example, measles, mild respiratory infections, mumps, gonorrhea or diarrhea are normally of greater importance in the army than the more fatal diseases, such as meningococcic meningitis, because they tend, if uncontrolled, to interfere to a much greater extent with training or combat activities.

As stated above, military preventive medicine is not concerned solely with the control of epidemic diseases. The individual soldier is the basic unit of any organization and the average mental and physical efficiency of the individual members of a unit will determine the degree of success which can be attained by the unit. Military preventive medicine must, therefore, offer methods of improving and augmenting the physical fitness of the individual soldier. For example, physical examinations, whether performed for the purpose of eliminating the physically unfit or to detect incipient defects, are an important part of military preventive medicine. Likewise, morale building activities, such as provision for suitable recreation, improve-

ment in living conditions, or the correction of environmental defects which, though they do not transmit disease, have an adverse effect on the physical wellbeing of the troops through their depressing effect on morale, are all closely related to or constitute a phase of military preventive medicine.

RESPONSIBILITY FOR HEALTH MEASURES

The commanding officer of any military organization, regardless of its strength or type, is responsible in all respects for that organization. He is, therefore, responsible for the health of the members of his command and, consequently, for the initiation and enforcement of suitable health measures. Certain procedures for the protection and promotion of the health of the troops, such as immunization against typhoid fever and smallpox, or the physical examination of all applicants for enlistment, are universal throughout the military service and are directed by the War Department. The commanding officer of a unit is not responsible for the initiation of such measures, but he is responsible for their enforcement within his command. In other instances, the commanding officer of a unit or a command must initiate measures to protect the health of his command, as, for example, in the control of a local epidemic or in the correction of insanitary environmental factors peculiar to the local situation.

With regard to the initiation of health measures, the Medical Department functions solely in an advisory capacity and exercises no command except in Medical Department installations. However, as Medical Department officers possess the necessary technical knowledge of and training in health work, the Medical Department in all echelons of the military service is charged with the responsibility for initiating and making the investigations, studies and surveys, and timely and pertinent recommendations which constitute a basis for the actual initiation of health measures by higher military authority.

The execution of health measures is directed by army regulations and by general and special orders as issued by the proper military headquarters. Army regulations, together with orders based on or in amplification of them, constitute the sanitary code of the army.

A given health measure is executed by the branch of the army which performs the activity required by that measure or

by the unit to which it pertains. The Quartermaster Corps is normally responsible for the prosecution of health measures involving the operation of utilities or the use of labor, especially where such measures affect more than one of the basic units of a command. Thus, the operation of water and sewage disposal systems are usually Quartermaster Corps activities and, generally, the Quartermaster Corps is charged with performing the actual work connected with the control of mosquito breeding places. The Corps of Engineers is responsible for the procurement and purification of water in a theater of operations, where water works or water distributing points are established.

If, because facilities are lacking or for any other reason, operating agencies, such as the Quartermaster Corps or the Corps of Engineers do not carry out the activities necessary to protect the health of a command, such work is performed by the units concerned. Thus, where a purified water supply is not furnished to troops, the purification of the water becomes a company function for which the company commander is responsible.

The Medical Department is responsible for the execution of health measures, the performance of which requires technical training, such as, for example, artifical immunization, inspection of food, or physical examinations. These activities are carried out by direction of higher military authorities in the same manner as any other activity within a military organization. In relation to the prosecution of other health measures, the Medical Department functions mainly in a supervisory capacity. This supervision is accomplished by means of inspections and studies with reports and recommendations to the coordinating military authority. The Medical Department does not furnish labor, funds or equipment for such activities as water purification, waste disposal, or insect control.

CHAPTER II.

BASIC PRINCIPLES OF MILITARY EPIDEMIOLOGY

Epidemiology is the science of epidemic diseases. It includes within its scope the etiology of communicable diseases, their transmission, prevalence, pathology, symptomatology and the application of measures to prevent or control their spread. Military epidemiology differs from that of civilian communities only in so far as the characteristics of a military population and the nature of a military environment modify the prevalence of disease and influence the effectiveness of the control measures (Chapter I).

A communicable disease is a disease caused by the invasion of the tissues of the body by living organisms which can be and are transferred from one human host to another. Certain of the diseases usually classified as communicable are not, under ordinary conditions, transmitted from one person to another. Some of the diseases of this type are tetanus, food infection acquired from the flesh of diseased animals, botulism and diseases in which an animal serves as the reservoir of infection, such as tularemia. The term "communicable disease" is synonymous with infectious disease, contagious disease and epidemic disease.

FACTORS GOVERNING THE SPREAD OF DISEASE

A communicable disease can become epidemic in a community only in the presence of certain conditions which govern the prevalence of the disease. The population as a group must be susceptible to the infection, that is, it must contain a sufficient number of susceptible individuals whose activities and environment are such that they will be exposed to the in-

fection. Transmitting agencies must be available in order that the causal organisms may be transferred from the source of infection to susceptible persons, and a source or sources of infection must be present and of such nature that the infection can reach a transmitting agency.

Group susceptibility. While an individual member of a community may be susceptible to and contract a communicable disease, other factors being equal, the prevalence of the disease will be limited or the severity of the ensuing epidemic will be determined by the susceptibility of the population of which he is a member. Group or community susceptibility is governed first, by the relative number of susceptible individuals in the community, second, by the characteristics of the population, and third, by the environmental factors which lessen or enhance the susceptibility of the individual to infection.

Effect of individual susceptibility on group susceptibility. A certain proportion of a given population must be susceptible to an infection in order for the incidence of the disease produced by that infection to attain epidemic proportion. If only a relatively small proportion of a population is susceptible to the disease in question, the probabilities that the infection will be transmitted to new and susceptible hosts are decreased, and for this reason the disease fails to spread or assumes only endemic or sporadic prevalence. During the progress of an epidemic the number of non-immunes is constantly decreasing, provided no additional non-immune persons enter the community. When the number of non-immunes has been reduced to below a certain proportion of the population, the incidence of the disease begins to decrease. Further reduction in the proportion of non-immunes present is accompanied by a rapid decrease in the number of cases until, because of lessened opportunities for the infection to be transmitted to susceptible persons, the disease ceases to spread.

A group as a whole is always more or less susceptible to a disease against which the individual is not rendered immune by an attack of the disease or in which immunity cannot be conferred by artificial means. Group resistance may be increased as the result of physical training and good living conditions, but nevertheless, there is little or no group resistance to such diseases as venereal infections or the common respiratory dis-

eases and their prevalence is governed only by the exposure rate or the virulence of the infecting organisms.

Effect of population characteristics on group susceptibility. Group susceptibility may be modified by certain characteristics of the population, such as the age distribution, social, economic and racial factors or the physical condition of the greater proportion of the individuals of the group. For example, communicable diseases tend to spread more rapidly and to attain a greater incidence among recruits than among well trained and physically fit troops, due in part to the relatively poor physical condition of recruits. Also, the nativity of the troops, that is, whether they are drawn from rural or urban localities, is an important factor in determining the epidemic characteristics of certain of the communicable diseases which may be introduced. Thus, where a force consists largely of men from rural districts, such diseases as measles and mumps tend to spread more rapidly and to attain a greater prevalence than among troops recruited from cities. The latter, having been subjected to more numerous opportunities for exposure to the infection during childhood have, as individuals, acquired an immunity not possessed by rural troops.

Effect of environmental factors on group susceptibility. Environmental conditions, aside from their effect on the facility with which infection is transmitted, also exert a marked influence on the susceptibility of the group. Exposure to adverse weather conditions, poor housing, inadequate food or clothing, or fatigue will decrease the resistance of troops to certain of the communicable diseases. Conversely, for example, a proper ration and suitable clothing and quarters serve to maintain or increase the resistance of the individual to infection, and thus prevent the spread, or decrease the incidence of communicable disease in a command as a whole.

Dissemination of infection. A communicable disease will spread through a community only when conditions are favorable for dissemination of the infective agents. For example, water-borne diseases will prevail only in the presence of a contaminated water supply; the spread of respiratory diseases is facilitated by crowding, and an insect-borne disease is transmitted from person to person only when the insect host of the causative organism is present.

CLASSIFICATION OF COMMUNICABLE DISEASES

Communicable diseases may be classified in a number of ways. They may be grouped according to the nature of the routes or agents of transmission, as for example, contact, water-borne or insect-borne diseases. The character of the etiological agent may be used as a basis for classification into such groups as bacterial and protozoal diseases. In other instances, diseases may be classified according to their principal pathologic feature or on the basis of their symptomatology. However, no classification is entirely satisfactory nor can all inclusive groups be formed on any basis. It is believed that, from the viewpoint of control, *communicable diseases* can be most satisfactorily classified into five groups, in four of which the diseases are grouped according to the principal factors concerned in the transmission of the etiological agents. The fifth class includes those miscellaneous diseases that are preventable but which cannot be placed in any one of the other four groups. The groups thus formed are as follows:

Respiratory diseases	Insect-borne diseases
Intestinal diseases	Venereal diseases
Miscellaneous diseases	

Respiratory diseases. Respiratory diseases are those diseases, the infective agents of which are usually disseminated in the secretions from the respiratory tract and transmitted by direct or indirect contact. These diseases are:

Measles	German measles
Influenza	Smallpox
Common colds (*coryza* and *common respiratory diseases*)	Chickenpox
	Septic sore throat
	Vincent's angina
Primary pneumonia (*lobar* and *bronchial*)	Whooping cough
	Poliomyelitis
Secondary pneumonia	Epidemic encephalitis
Mumps	Psittacosis
Meningococcic meningitis	Pulmonary tuberculosis
Diphtheria	Pulmonary plague
Scarlet fever	

Septic sore throat is, in many instances, transmitted by milk, but as the causative organisms are usually present in dis-

charges from the mouth and nose, it is classified as a respiratory disease.

Intestinal diseases. Intestinal diseases are those diseases, the infective agents of which are discharged from the body in the feces and urine and are usually transmitted by food and water. Invasion of the tissues usually occurs in the alimentary tract. The intestinal diseases are:-

Typhoid fever	Cholera
Paratyphoid fevers	Helminthic infestations
Common diarrhea	Undulant fever
Bacillary dysentery	Food infection
Protozoal dysentery	Botulism

Undulant fever is not, strictly speaking, a communicable disease as it is not normally transmitted from person to person. However, it can be transmitted from animals to man in food and, for this reason, it is included in the intestinal disease group of communicable diseases.

Insect-borne diseases. Insect-borne diseases are those diseases which are usually transmitted by bloodsucking insects. The insect-borne diseases which are the most important to American troops are:

Malaria	Trench fever
Dengue	Relapsing fever
Typhus fever	Bubonic plague

Other diseases which are transmitted by bloodsucking insects and which might, under certain conditions, be encountered among American troops, are:

Yellow fever	Rocky Mountain spotted fever
Filariasis	Tularemia
Pappataci fever	Tick paralysis

Rocky Mountain spotted fever, tularemia and bubonic plague are not, as a rule, transmitted from person to person but from animal to man. They are not, therefore, communicable diseases within the usual definition but, as they are transmitted by insects, they are included in the insect-borne group of communicable diseases.

Tularemia may be and usually is transmitted to man by agencies other than insects (Chapter XX). It is not, therefore,

insect-borne in the same sense as malaria, but as the infection is usually transmitted among the animal hosts by insects, it is classified as an insect-borne disease.

Venereal diseases. Venereal diseases are those diseases in which the infection is usually transmitted by direct contact during sexual intercourse. The diseases classified as venereal diseases are syphilis, gonorrhea, chancroid and lymphogranuloma inguinale.

Miscellaneous diseases. The diseases classified as miscellaneous are those preventable diseases which, because of their epidemiological characteristics, cannot be placed in any one of the four groups considered above. Many of the miscellaneous preventable diseases are not communicable in the sense that they are transmitted from person to person. These include infections which are primarily diseases of animals but are transmissible to man, as well as diseases due to food deficiencies. In some of the miscellaneous communicable diseases, the transmission agency is unknown, while in other instances the infection is transmitted by direct or indirect contact.

The diseases of this group which are potentially the most important in a military force are:

Yaws	Scabies
Infectious jaundice	Rabies
Trachoma	Tetanus
Scurvy	Anthrax
Beriberi	Granuloma inguinale
Tinea cruris	

SOURCES OF INFECTION

The primary source of infection of most of the communicable diseases is the human case or carrier, but in certain diseases, such as plague or some types of food infection, animals may constitute the reservoir of infection or the immediate source from which the infection is transferred to man.

While the infective agents of many of the communicable diseases may be acquired from either carriers or cases, the relative importance of carriers and cases as sources of infection varies according to the disease. The case to case transference of infection without the intervention of a carrier is the usual route of transmission in the spread of such diseases as measles,

mumps, and the venereal diseases. In a military population, the case to carrier and carrier to carrier, or carrier to case, is normally the channel by which the causal organisms of such diseases as meningococcic meningitis, primary pneumonia, diphtheria, or scarlet fever are transmitted.

Except for the comparatively short time that a military unit is engaged in actual combat, it is usually, as a unit, in more or less direct contact with a civilian population and the troops are, therefore, exposed to sources of infection within the civilian community. A communicable disease may spread from soldier to soldier within a command or the prevalence may be maintained wholly or in part by the exposure of susceptible troops to sources of infection in the surrounding civilian population. Venereal diseases are derived entirely from the civilian population and do not spread from soldier to soldier. In other instances, control measures may be adequate to prevent or reduce to a minimum the transference of infection within a command, but extra-military exposures may be sufficient to initiate and maintain endemic or epidemic prevalence. Thus, for example, at a camp or station where the water and food supply are protected from contamination, the troops may come into contact with sources of intestinal infection in the civilian community to such an extent as to produce an epidemic. Or in other instances, the food and water supplies obtained from civilian sources for use by the troops may be contaminated and produce epidemics of diseases where there is no transmission of the infection from person to person within the command.

Carriers. A carrier of a disease is a person in whose tissues the causative organisms of the disease are being propagated and who is discharging these organisms from the body, but who is, at the same time, apparently healthy and does not exhibit clinical manifestations of the disease in question. The organisms may be conveyed from the body in the discharges from the respiratory tract or in the feces or urine, and elimination may be constant or intermittent.

Carriers are classified as healthy, incubationary, and convalescent, and these types are again classified, for administrative purposes, as chronic and temporary.

Healthy carriers. A healthy carrier is one who throughout the known carrier period presents no symptoms of the disease. The organisms may be originally acquired by contact

with a case or another carrier of the infection, or they remain and continue to be propagated in the tissues after an attack of the disease. A healthy carrier is also known as a passive carrier, and the carrier state usually occurs in a person who is immune or resistant to the disease.

Among the diseases which are known to be transmissible by healthy carriers are the following:

Typhoid fever	Dysentery (bacillary and protozoal)
Paratyphoid fevers	Meningococcic meningitis
Pneumonia	Diphtheria
Cholera	Scarlet fever.

Incubationary carriers. Incubationary carriers are persons who, while in the incubationary stage of a communicable disease, discharge the infective organisms of that disease in such a manner as to transmit them to others. The incubationary carrier is actually an early case of the disease and many of the communicable diseases can be transmitted by incubationary carriers. This type of carrier is of particular importance in the transmission of those diseases which have a comparatively long incubation period, such as measles, mumps, smallpox and typhoid fever.

Convalescent carriers. Convalescent carriers are those who continue to discharge the infective organisms of the disease during the convalescent stage of a communicable disease and for some time after clinical recovery from the disease.

Convalescent carriers are of particular importance in the transmission of diphtheria, meningococcic meningitis, typhoid and paratyphoid fevers and bacillary and amebic dysentery.

Temporary carriers. A temporary carrier is one in whom the carrier state disappears within a relatively brief period of time, which is usually considered, arbitrarily, as any length of time less than three months after contact with the source of the infection or subsequent to recovery from the disease. The majority of the convalescent carriers, and also healthy carriers who have obtained their infection by contact, are temporary carriers. Incubationary carriers are, necessarily, temporary carriers.

Chronic carriers. A chronic carrier is one in whom the carrier state persists for a long period of time which, for ad-

ministrative purposes, is considered as more than three months. Chronic carriers are usually healthy carriers who become such following an attack of the disease which may or may not have been diagnosed. Occasionally, an immune individual may become a chronic carrier by contact with a case or carrier. Chronic carriers are important factors in the spread of typhoid fever. They are also concerned in the spread of other diseases, such as diphtheria and meningococcic meningitis.

Suspects. A suspect is a person who, after having been exposed to an infectious disease, exhibits one or more of the prodromal symptoms of that disease, but does not, for the time being, present symptoms which would justify a positive diagnosis.

Contacts. An individual contact is a person who has been exposed to an infectious disease but does not present any of the symptoms of the disease. Usually, from a practical administrative viewpoint, contacts are considered to be persons who have been associated with cases or carriers of a communicable disease. However, those who have consumed water or food contaminated with the causative organisms of an intestinal disease, or have been exposed to the bites of insects which might be the transmitting agents of an insect-borne disease, are also contacts.

Close contacts. A close contact is a person who has been closely associated with a person who has a communicable disease, the causative agents of which are transmissible by contact. Generally, close contacts are considered to be those who have been quartered in the same tent or squad room with the case, have been seated near him at mess, or otherwise intimately associated with him. Close contacts are of special importance in the spread of such diseases as measles and mumps, and in the production of carriers of meningococcic meningitis, diphtheria and pneumonia.

Remote contacts. Remote contacts are persons who have been in contact with close contacts, either directly, or indirectly through other remote contacts. The remote contact is an important factor in the dissemination of infection in those diseases that are usually spread by carriers.

The contact group. A contact group is a number of individuals who, as a group, but not necessarily as individuals, have been in close contact with a case of communicable dis-

ease, which is transmissible by contact, under circumstances which would render probable the exposure of any or all members of the group. The contact group is, therefore, composed of persons who, if they are susceptible to the disease, are potential secondary cases or may become carriers of the infection.

Cases. For the purpose of classification as sources of infection, cases of a communicable disease are divided into primary and secondary cases, and as known and missed cases.

A primary case. A primary case is the first case of a given communicable disease occurring in a command or group at a time when no other known cases of that disease are present.

A secondary case. A secondary case is a case which occurs as a result of infection obtained directly or indirectly from a primary case.

Known cases. Known cases are, as the term indicates, cases in which the diagnosis of the disease in question has been made.

Missed cases. Missed cases, as distinguished from known cases, are cases in which the disease is not diagnosed during illness or at least not during the infectious period. The fact that they have occurred becomes apparent when circumstances indicate that they have given rise to secondary cases or have served to produce carriers.

Missed cases are usually mild, subclinical or atypical cases that occur at the beginning of an epidemic and not infrequently are the primary cases from which secondary cases are derived. Frank missed cases do not ordinarily occur during the progress of an epidemic, for after an epidemic is established or when the disease is known to be present in a command or in the surrounding civilian population, a mild case which might otherwise be missed is usually diagnosed.

PRINCIPLES OF DISEASE TRANSMISSION

While a military force is a part of the surrounding civilian community, the military community is, nevertheless, in many respects, a universe distinct from the civilian community. The group susceptibility of many military units, particularly those which are newly organized, is higher for certain diseases than is usually the case with a civilian population. The crowding

in barracks and tents, on trains and ships, and in the field during training, which is necessarily a part of the military environment, is especially conducive to the spread of those diseases that are transmissible by contact. On the other hand, the physical training which a soldier receives increases his resistance to disease, and military authority and discipline are potent factors in the adequate and uniform enforcement of measures for the control of communicable diseases.

Transmission agencies. In order for a disease to spread, agencies must be available by which the infective organisms can be transmitted in large numbers from the source, which may be a case or a carrier, to susceptible persons. In many diseases, the organisms can be transferred by two or more agencies but the principal or usual transmission agency for a given disease is determined by the portals of entry and exit by which the organisms invade, or escape from the tissues of the host. The transmission agencies are contact, food and water (including anything that enters the mouth and is swallowed), and insects.

Contact. The term contact, as used to describe a transmission agency, includes not only direct and immediate contact, but also indirect contact where but a relatively short time elapses between the discharge of the organisms from the disseminating source and the completion of their transference to other persons. When transferred by contact, either directly or indirectly, the organisms or virus remain in the material in which they are discharged from the body.

Direct contact. When a disease is transmitted by direct contact, the infecting organisms are passed directly, without the intervention of any object or substance, and usually by inoculation, from the tissues of the infected person to the tissues of the susceptible individual. Venereal diseases are ordinarily transmitted by direct contact between persons.

Indirect contact. Transmission by indirect contact is the transference of the organisms from person to person by an intervening object or substance, on or in which the organisms remain in the material in which they are discharged, such as secretions from the respiratory tract, or feces or urine.

Air is one of the principal mediums by which indirect contact is accomplished as it serves to transport droplets of fluid containing pathogenic organisms from the respiratory tract of

one person to the respiratory tract of another (page 32). In other instances of transmission by indirect contact, the hands and inanimate objects, such as eating utensils, or any articles used in common by two or more persons, serve to transfer the infectious material from person to person.

Certain of the pathogenic organisms will not survive for any considerable period of time when separated from animal tissues or from the discharges from the animal body, and the dissemination of these, as well as those that are ordinarily discharged from and invade the tissues via the respiratory tract, is normally limited to transference by indirect contact through the air, by the hands or by articles contaminated with the infected discharges.

Measles and mumps are examples of diseases which are, as a rule, transmitted solely by contact. Diphtheria and scarlet fever are usually transmitted by contact but are also occasionally transmitted by foods, especially by milk. On the other hand, the intestinal diseases may be, and are at times, transmitted by indirect contact, but the etiological agents of these diseases are more frequently transmitted by food and water.

Food and water. Food and water are the usual transmission agencies for those organisms that are excreted in the feces and urine and invade the tissues of the body from the alimentary tract.

Insects. Insects serve as transmission agencies in the dissemination of certain diseases, either as intermediate or definitive hosts for the parasite or as mechanical carriers. Blood sucking insects constitute the complete and sole transmission agency for those diseases in which the infective organisms are found only in the body fluids. Non-biting insects may act as mechanical carriers in the transfer of infected discharges from person to person, but more commonly serve only as subordinate transmission agencies by conveying pathogenic organisms from human excreta to food.

Principal and subordinate transmission agencies for the different diseases. In the presence of environmental conditions which are unaltered by disease control measures, the greater number of the cases of any communicable disease will be caused by organisms transmitted by a particular agency, other and subordinate agencies being responsible only for the transmission of a relatively small proportion of the infection.

Thus, under these conditions, the principal transmission agencies for typhoid fever are water and food, but contact may be a subordinate agency. Diphtheria is transmitted principally by contact, but a food, such as milk, may play a subordinate role in the transmission of this disease.

Control measures may change the environmental conditions so that a subordinate transmission agency becomes the principal or only transmission agency. For example, if the water supply is purified and the food protected from contamination, intestinal diseases might be spread by contact with carriers and cases. However, when a subordinate agency only is available the prevalence is usually much less, other factors being equal, than when the organisms are transferred by an agency which is normally the principal agency of transmission.

Respiratory diseases. Contact is the principal transmission agency for respiratory diseases in general. Food, especially milk and milk products, may be an important subordinate agency in the transmission of scarlet fever, diphtheria and septic sore throat.

Intestinal diseases. Food and water constitute the principal transmission agencies of intestinal diseases, but contact may also serve as a subordinate transmission agency, particularly in the case of the more virulent infections, such as bacillary dysentery or cholera.

Insect-borne diseases. Blood sucking insects are the principal, and in many instances the only, transmission agencies of insect-borne diseases which are transmitted naturally by a biting insect. Some of the insect-borne diseases, such as tularemia or plague, are also transmitted by contact.

Venereal diseases. Contact is the principal and practically the only transmission agency of venereal diseases. Except in rare instances, venereal infection is transmitted by direct contact during sexual intercourse. Occasionally, the infection is transmitted by kissing, by contact with infected body fluids during surgical operations, or by contact through contaminated towels or clothing.

BASIC PRINCIPLES OF DISEASE CONTROL

The primary objective of all disease control measures in a military force is to promote military efficiency by preventing a

communicable disease from attaining such prevalence that it will interfere with the mission of the command concerned. Measures designed to attain this objective may favor the production of secondary cases within a relatively small exposed group, but in so doing afford protection for the major portion of the command. This is true in the operation of a group quarantine of contacts of a primary case, or in the employment of detention camps for the observation of recruits.

Any and every procedure, the results of which will promote the accomplishment of the military mission, should be employed. If, however, the employment of a disease control measure will interfere with or delay the accomplishment of the military mission more than would the uncontrolled prevalence of the disease it is designed to control, or the prevalence resulting from a less effective control measure, that measure cannot be justified and should not be adopted.

In order for a disease to spread in a population, the relationship between the agency or agencies of transmission and the source or sources of infection on one hand and susceptible persons on the other must be such that the infection can reach the transmitting medium and be transferred thereby to the susceptible persons. Therefore, fundamentally, a disease control measure may provide for the control of the source of infection; it may prevent the transference of infection or reduce the effectiveness of a transmitting agency, or it may protect the susceptible members of the community.

Control of the source of the infection is effected by control of the case, suspect, carrier or contact. It is accomplished generally by the isolation of the case, carrier or suspect, and by quarantine of contacts. The transference of infection from the source to susceptible persons is prevented or inhibited by control of the transmission agency, as, for example, by insect eradication or purification of the water supply. Susceptible persons are protected against a disease by being prevented from coming in contact with a source of infection or an infected transmitting agency, and by immunization.

The control of a communicable disease may be accomplished by the control of only one of the basic factors, that is, by control of either the source of infection or the transmitting agency, or by the protection of susceptible persons. Usually, however, the control of more than one of these basic factors

is indicated and in the control of certain diseases, such as typhoid fever, measures are available for the control of the source of infection and the agencies of transmission, and for the protection of susceptible persons by immunization.

Isolation. Cases, carriers or suspects may be placed in isolation for treatment and observation. Isolation serves to separate the source of infection from the transmission agencies. Isolation may be by groups or the individual may be isolated. For example, group isolation is practiced in the hospitalization of malaria cases in screened, mosquito-free buildings to prevent the transmission of the infection to mosquitoes, although the cases are not separated one from the other or from patients with other diseases. A number of cases, carriers or suspects of the same disease may be isolated as a group. A patient having a disease transmissible by contact can be isolated in a ward with patients having other diseases, provided measures are taken to prevent cross infections. In other instances, particularly in the control of contact diseases, a single case may be isolated as an individual to prevent the transmission of the infection by droplet infection.

Quarantine. Quarantine, as employed in a military force, is the separation of a group containing individuals who are actual or potential sources of infection from the remainder of the command for the purpose of preventing the transmission of the infection. Usually, it is employed as a method of preventing the spread of disease by incubationary carriers or by mild or missed cases, and for the purposes of facilitating the detection of secondary cases or carriers and restricting their occurrence to a single group. Rarely, an entire command may be quarantined to prevent the spread of infection from the command to the civilian population, or *vice versa.*

Group quarantine (*working quarantine*). Group quarantine is the restriction of a contact group under conditions which will prevent the dissemination of the infection to unexposed members of the command, but will permit the group as a whole to continue training. The group may consist of a squad, platoon, or even a company and is usually administered and trained as a unit during the quarantine period.

The group quarantine method is commonly employed in the control of diseases which tend to spread from case to case without the intervention of healthy carriers or of a transmitting

agency which would not be affected by the quarantine. Measles and mumps are examples of diseases which, under proper conditions, can be controlled by group quarantine. Usually, group quarantine is not an effective method of preventing the spread of such diseases as meningococcic meningitis, in which healthy carriers are common and there is a consequent tendency towards sporadic prevalence. Nor is group quarantine indicated where the source of infection is outside the group in which the primary case occurs and the infection is transmitted by an agency generally common to the entire command, as, for example, in the control of an intestinal disease transmitted by food, or an insect-borne disease.

Group quarantine has the disadvantage that it does not prevent, but, in fact, favors the continued exposure and infection of all susceptible members of the quarantined group. Group quarantine is not an efficient control measure when the infection is widespread through a command, but where the prevalence is sporadic or only a few cases have occurred, it affords a means of limiting the occurrence of the disease to the quarantined group.

The quarantine period. The length of the quarantine period for a group is governed by the length of the incubation period of the disease. It begins with the removal from the group of the primary diagnosed case and, if no secondary cases occur within the group, it terminates at the end of a period corresponding in length to the maximum incubation period of the disease. If secondary cases appear within the quarantined group, the quarantine period is extended until the number of days corresponding to the length of the maximum incubation period of the disease have elapsed since the removal of the last secondary case.

Administration of group quarantine. The quarantined group is quartered, messed, trained and performs routine duties separate from other troops. The members of the group are inspected once or, if practicable, twice daily by a medical officer for the purpose of detecting those having clinical symptoms of the disease. When found, these individuals are immediately removed from the quarantined group for further observation in hospital. Where indicated and practicable, all, or a selected number of the members of the group, are examined to determine if they are carriers of the infection. Carriers are removed from the group

for quarantine as individuals or as carrier groups, or for treatment in hospital.

The group is released from quarantine when it is free from infection, as indicated by the non-occurrence of new cases during a period of time corresponding to the length of the incubation period subsequent to the detection of the last case and, if carrier surveys are made, by the absence of carriers.

The quarantine camp. In training or mobilization camps or at the larger stations where a communicable disease prevails, a quarantine camp may be established for the purpose of segregating groups of contacts or carriers. The men in quarantine camps should be housed in barracks or huts, but tentage may be employed if necessary. Provision should be made for housing and messing small groups separately so that infection will not spread from group to group. If more than one disease is present, contacts exposed to the same disease should be grouped so as to prevent further spread of the infection. Carriers should be grouped in the same manner.

The men held in a quarantine camp should be examined once, or preferably twice, daily for evidence of the disease in question and suspects should be hospitalized at once. If the disease is one that tends to produce healthy carriers, an intensive search for carriers among the quarantined groups should be made. The carriers are treated, if treatment is indicated, and remain in quarantine until they are no longer infectious.

A quarantine camp may be, and frequently is, administered by the Medical Department or operated as, or in connection with, a Medical Department installation.

Detention and observation of recruits. Recruits coming into a military force from civil communities may be incubationary carriers or early cases of a disease transmissible by contact. Where large groups are being received at a camp or a station, they serve to concentrate in that camp or station all the infections prevailing in the communities from which they are drawn. In time of mobilization, recruits proceeding by troop trains from their home areas to training camps are frequently exposed to infection, or are sources of infection for others, while enroute.

At any time, either in peace or during mobilization, recruits are potential sources of infection, and to that extent a

menace to the command they join. Measures should, therefore, be taken to prevent contact between them and other troops before they are free from infection. This is accomplished, where practicable, by the detention of all recruits in group quarantine. Where recruits are being received singly or in small numbers their detention in group quarantine may be impracticable from an administrative viewpoint and they must be assigned directly to the organizations of the command. They should, however, be examined daily during the first two-week period for evidence of communicable disease.

Detention camps. In training and mobilization camps where recruits are being received in groups or in comparatively large numbers, they should be placed in a detention camp for sufficient time to permit the development of prodromal symptoms of any disease to which they may have been exposed, and thus prevent the introduction of communicable diseases into a non-infected command.

The detention period for a given group should, as a rule, be not less than 14 days, where no communicable diseases develop. If a case or cases of infectious disease occur, the detention period is prolonged until the infection is eradicated from the group.

Recruits held in detention camps may be equipped, vaccinated and given a certain amount of training while in detention. In order to prevent continued or repeated exposure of the detained men by incoming recruits, each new increment should be organized into squads or platoons, each of which is quartered, messed and administered separate from the others. Each man should be examined at least once daily by a medical officer for symptoms of infectious disease.

Every case of communicable disease found among the detained men should be immediately hospitalized and all close contacts placed in group quarantine in the detention camp or, preferably, in a quarantined camp.

A detention camp, as distinguished from a quarantine camp, is not a Medical Department installation nor is it administered by the Medical Department. The Medical Department is, however, actively and continuously engaged in supervising the health of the detained men and in searching for early cases and carriers of communicable diseases.

Control of transmitting agencies. The control of disease through the control of transmitting agencies is accomplished by so modifying certain environmental factors as to prevent the transmission of the causative agents of disease. This method of disease control involves, for example, the purification of water supplies, the control of disease transmitting insects, the proper disposal of infected wastes or the correction of housing defects. The methods employed to control transmission agencies are discussed in detail in succeeding chapters in connection with the control of the various diseases.

Immunization. Immunization is practiced routinely in the control of typhoid and paratyphoid fevers and smallpox. Where indicated, it may be used in the control of diphtheria, cholera or plague. Artificial immunization does not confer permanent, absolute immunity to the extent of rendering a group completely nonsusceptible to the disease concerned. Thus, while immunization against typhoid and paratyphoid fevers will render the greater proportion of a group immune for the time being against a moderate dose of the infection, it does not protect all individual members of the group against continued massive doses nor does the immunity last for an indefinite period of time without further vaccination. Artificial immunization should be employed in the control of these diseases in conjunction with and for the purpose of augmenting the control of transmitting agencies. In the control of smallpox, artificial immunization is the only control measure of practical value and must be repeated at intervals to maintain a protecting degree of immunity.

Treatment as a preventive measure. Early or prophylactic treatment may be employed in the control of certain diseases to prevent the development of symptoms. Thus, malaria may be controlled by prophylactic treatment with quinine during a period of exposure to the bites of infected mosquitoes, or venereal disease can be prevented by the use of chemical prophylaxis immediately after exposure to infection.

Discipline and physical training. Military discipline insures the cooperation of the individual in the enforcement of disease prevention and health promotion procedures, and is also an important factor in securing uniformity in the employment of health measures throughout a command. The success of many disease control procedures depends wholly or in

part on the cooperation of the officers and enlisted men, that is, on the discipline of the command. The employment of chemical prophylaxis in the control of venereal diseases, the use of mosquito bars to protect the troops from the bites of infected mosquitoes, or the maintenance of proper air conditions by window ventilation are some of the many measures in the enforcement of which discipline plays an all important role.

Military discipline and physical training are, in a sense, synonymous, in that one cannot be attained without the other. Aside from any question of specific immunity to disease, the trained soldier is more resistant to infection than the recruit. To recruits, generally, the military environment is strange and at times depressing; they are unaccustomed to the physical exertion incident to military training, and they react quickly and unfavorably to cold and exposure. The trained man does not become unduly fatigued by the performance of military work and he is able to withstand exposure to cold without excessive loss of body heat. These factors, together with the general nonspecific resistance to infection conferred by continuous close contact with others, tend to render the trained soldier less susceptible to disease than the raw recruit.

CHAPTER III.

CONTROL OF RESPIRATORY DISEASES

The respiratory diseases generally are transmitted from person to person by contact. The infective agents are ordinarily contained in the secretions and discharges from the respiratory tract of the person having the disease, or one who is a carrier of the infection, and are transferred to the mouths and respiratory tracts of others principally by the air, by the fingers and by eating utensils, dishes and drinking cups. Recent studies indicate that eating utensils and dishes are more important in the transfer of the etiological agents of respiratory diseases from person to person than was formerly believed to be the case. Food may serve as a transmitting agent, particularly milk, and uncooked foods or cooked foods which have been contaminated subsequent to cooking.

General prevalence and importance. From the viewpoint of their effect on military activities and operations, the respiratory infections as a group, and more particularly measles, mumps, influenza and the common respiratory diseases, are the most important of the communicable diseases that occur in the military forces. These diseases are readily transmitted by casual and transient contact and tend to occur as explosive epidemics. During the progress of an epidemic a comparatively large number of men are incapacitated, with the result that the efficiency of the units to which they belong is correspondingly impaired.

The diseases against which an attack confers more or less permanent immunity, principally measles and mumps, are much more prevalent among soldiers who resided in rural districts prior to enlistment than among those drawn from urban

communities. This is probably due to the fact that the latter have had, as a group, more opportunities to contract these diseases during childhood. While the incidence of other diseases, such as influenza and common colds, is generally somewhat lower among troops from urban communities than among those from rural districts, there is not sufficient difference in prevalence to justify consideration of nativity in the formulation and execution of control measures.

Because of the relatively large number of immunes, American troops show a low group susceptibility to whooping cough, German measles, chickenpox, poliomyelitis, diphtheria, and scarlet fever. Consequently, serious epidemics of these diseases seldom occur in military organizations.

Respiratory diseases in general tend to increase in prevalence and become epidemic during the late autumn, winter and early spring months. This seasonal variation is, no doubt, due largely to the greater tendency to remain indoors under crowded conditions with the consequent increase in the exposure rate, and to the adverse effects which poor ventilation and exposure to inclement weather have on the resistance of the tissues to infection.

Troops who have had relatively long military service have a higher group resistance to respiratory diseases generally, and especially to such diseases of the respiratory group as influenza and the common respiratory infections, than do recruits or men who have been in the military service for a short time only. This non-specific immunity is probably due to several factors. The close contact between individual members of a military organization probably results in an increased exposure to small doses of infection, accompanied by the development of temporary immunity. Further, trained troops are more amenable to discipline, and control measures can be more efficiently executed with trained troops than with recruits.

GENERAL CONTROL MEASURES

Measures for the control of respiratory diseases are, as a rule, designed to prevent contact between carriers and cases and susceptible individuals, to minimize the dispersion and

distribution of the infective agents, or to maintain or promote resistance to infection on the part of the individual.

In most instances, the principal purpose of measures for the control of a respiratory disease is to retard the progress of an epidemic. This is especially true in the control of diseases which tend to occur as explosive outbreaks, such as, for example, influenza and the common respiratory diseases. If the spread of the disease in question through the command can be retarded, fewer men will be incapacitated at any one time and there will be less interference with the military activities of the command. Also, delay in the spread of a respira-

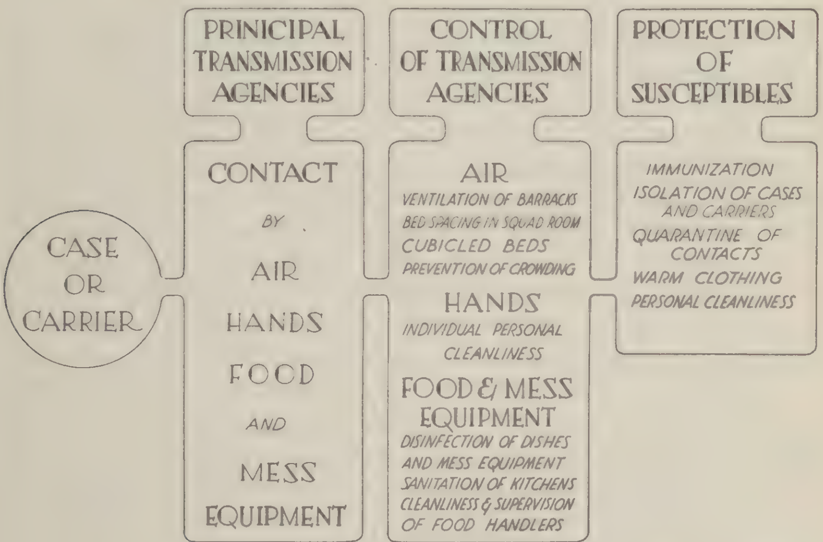

FIG. No. 1. General factors in the control of respiratory diseases.

tory disease will lighten the current load on the hospital facilities and permit of better care of each patient. Further, if the explosiveness of an epidemic is diminished, it is probable that ultimately the number of cases will be reduced. In other instances, particularly in the control of measles, scarlet fever, meningococcic meningitis and mumps, the occurrence of an epidemic may be prevented by the removal of the sources of infection and by the detection and isolation of the primary cases or carriers. Diphtheria and smallpox are controlled by specific measures (pages 81 and 95).

Crowding. Crowding, or close contact between individuals, facilitates the transmission by air of the infected secretions and increases the opportunities for their transference by contaminated hands and articles that are handled in common by many persons. Crowding and the consequent close contact between infected and non-immune persons, is, therefore, a most important factor in determining the rate of spread and the extent of an epidemic of any respiratory disease.

Droplets of fluid are expelled from the respiratory tract by forceful breathing, coughing, talking or sneezing and such droplets may contain pathogenic bacteria or viruses. Droplets which remain unevaporated respond to the law of gravity and settle out of the air within a few seconds, and, in the absence of air currents, they tend to travel only a short distance, usually only a few feet, before falling to the floor or ground. Small droplets may however evaporate before reaching the floor or ground, leaving the droplet nuclei of residue containing infective material. The droplet nuclei may remain floating in the air for a comparatively long period of time, usually for minutes and sometimes for hours, and serve to carry infection for relatively long distances. The humidity of the air and its effect on the evaporation of the droplets and the velocity of the air currents influence to a considerable degree the transmission of infection by air.

As long as there are two persons in a room it would be impracticable to exclude the possibility of infection being carried by the air from one to the other. However, the separation of individuals by a greater or less distance (*infra*) reduces materially the transmission of infection by droplets and to some extent by droplet nuclei.

In military organizations, the greatest degree of crowding ordinarily occurs in squad rooms, at mess, in day rooms and recreation centers, at military formations, such as close order drill, in offices and in theaters. Basically, the control of crowding is a question of increasing the spacing between individuals to an extent which will minimize the transmission of air-borne organisms. Complete prevention of crowding cannot be accomplished by any practical measures. Crowding can be partially controlled, and the exposure rate proportionately reduced, by increasing the distance between beds in squad rooms and between men at mess, by reducing to a minimum all drill

and other military activities which will bring the men close together, by preventing undue grouping in day rooms, gymnasiums, or other places of recreation, by permitting occupancy of only alternate seats or alternate rows of seats in theaters, and like measures.

In the absence of air currents most of the unevaporated and infected droplets will settle out of the air within a very short time and within a few feet after being expelled from the lungs. As a working rule it may be considered that the separation of individuals by a distance of more than five feet affords a measure of protection from droplet infection.

The presence of a serious epidemic of respiratory diseases, or the impending danger of such an epidemic, may justify closing the theaters and the suspension for the time being of training or other military activities requiring the grouping of large numbers of men. However, extreme measures of this kind have an adverse effect on morale and should not be hastily invoked nor should they be adopted unless absolutely necessary. Idle troops will, in any event, crowd together in service clubs and day rooms and thus nullify the good results which might be obtained from other measures to prevent crowding.

The most dangerous crowding is that which occurs between the sleeping occupants of squad rooms. The deep breathing and forcible exhalations which occur during sleep serve to propel the infected droplets and droplet nuclei from the respiratory tract for a maximum distance through the air.

In the control of respiratory diseases, all space available for quarters should be utilized and the total number of men in any one room reduced to a minimum (page 141). Barracks space should be supplemented by tentage where necessary and practicable, provided the troops quartered in tents will not be subjected unduly to inclement weather. Bed spacing is discussed further under housing of troops (page 139).

Cubicles. Where there is danger that infection may be transmitted by the air, the beds in squad rooms and hospital wards should be separated and protected by screens arranged so as to convert each bed space into a cubicle (Fig. No. 2). The cubicle screen may consist of a shelter tent half, sheet, blanket, large pillow case, or any piece of cloth of similar size, or, if necessary, of boards or other material (Figures No. 2 and 3).

FIG. No. 2. Method of constructing cubicles in squad rooms by the use of shelter tent halves with head and foot arrangement of beds.

The cubicle screen, of whatever material it may be made, is so installed that it will prevent the passage of exhaled droplets from the occupant of one bed to the occupant of another. In the squad room, the shelter tent half provides an effective and practical cubicle screen. It has an additional advantage in that it is usually available as a part of the equipment of the individual soldier, and is, therefore, readily obtainable. Sheets or operating room screens are more commonly used for this purpose in hospital wards (Fig. No. 3).

A cubicle screen should extend to not less than two feet nor more than four feet above the surface of the bed at the head of the bed. The height above the bed may be decreased towards the foot of the bed, or no screen may be used opposite the lower half of the bed. If cubicle screens are too low or too short, vertical currents of the warm exhaled air may carry the infected droplets over the upper edge or around the ends to adjoining beds. If they are too high they will interfere unduly with air movement and ventilation. The screen should, in all instances, extend below the surface of the bed.

FIG. No. 3. Cubicles made by hanging sheets between beds. This method is usually preferred in hospital wards.

The shelter-half cubicle screens may be secured in place by the shelter tent poles, by sticks or by iron rods fastened to the bed or cot. Sheets or blankets may be hung on transverse or vertical wires (Fig. No. 3).

In the presence of an epidemic, the beds in squad rooms should always be separated by cubicle screens. Cubicles may be employed to an advantage in the control or prevention of respiratory diseases in a squad room, even when no known carriers, cases, or suspects are known to be present in the room in question. Cases, suspects or carriers of respiratory diseases, when housed in hospital wards, should be separated from each other, and from patients with other diseases, by cubicle screens.

Quarantine. The absolute quarantine of all contacts of respiratory diseases would prevent the spread of the infection to the unexposed members of the command. However, the effect on the activities of a military organization resulting from an absolute quarantine of any considerable number of contacts ordinarily renders the adoption of such a measure impracticable.

Group quarantine of contacts is, under certain conditions, a practical measure for the control of some of the respiratory

diseases (page 23). This method of quarantine is the most useful in the control of measles, and, to a lesser extent, of diphtheria and scarlet fever. These diseases are spread principally by close and definite contact, and remote and casual contact is seldom an important factor. Further, the primary cases are more frequently diagnosed in their early stages than in many of the other respiratory diseases. As a rule, an epidemic begins slowly and is not explosive in character, or at least does not become so until after secondary cases develop. For these reasons it is possible, in many instances, to institute a group quarantine which will include all the contacts who would, if unrestrained, spread the infection through a command.

Group quarantine is usually of little value in the control of influenza or the common respiratory diseases, such as acute coryza or common colds. These diseases tend to be transmitted by rather transitory and casual contact and the primary cases are, as a rule, mild and pass undiagnosed. Epidemics are explosive in character and tend to progress rapidly, and the chances are remote that group quarantine will include a sufficient proportion of the contacts to prevent or modify the progress of an epidemic. Group quarantine may, however, be successful in controlling influenza and the common respiratory diseases when operated in conjunction with quarantine or detention camps for recruits, at least to the extent of preventing the spread of these diseases to the rest of the command. The administration of a group quarantine is described on page 24.

If a secondary case occurs outside the quarantined group, the contacts of that case are also placed in group quarantine. The number of groups that can be profitably quarantined depends somewhat on the strength of the command and local conditions. As a rule, however, under average conditions, if it becomes necessary to quarantine more than three groups, group quarantine will no longer be an effective method of controlling the spread of the disease.

Quarantine or isolation in hospital of cases of respiratory disease is an essential procedure in the control of epidemics. Precautions should be taken in all instances to prevent the transmission of infection by such articles as thermometers.

towels, dishes, bedding, urinals, bedpans, wash basins, or by the hands or clothing of attendants.

Ventilation. It is essential in the control of respiratory diseases that squad rooms be properly ventilated. Poor ventilation, with the resulting increase in humidity or atmospheric temperature, or both, lessens the resistance of the tissues of the respiratory tract to invasion by the etiological agents of respiratory diseases. It is probable that, as a general rule, a much smaller dose of the infecting organisms will produce infection in the presence of poor air conditions than when rooms are properly ventilated.

The training of company officers and noncommissioned officers in the methods of ventilating squad rooms and the instruction of all personnel in regard to the need for ventilation is an important feature in the prevention or control of respiratory diseases. Such training should be given or supervised by medical officers. The principles of ventilation and methods of ventilating barracks and tents are discussed in Chapter IV.

Medical inspection. The early detection and isolation of those sick with respiratory disease is a valuable control measure. Daily medical inspection for the purpose of detecting incipient cases is a part of group quarantine (page 35), but daily inspection of an entire command by medical officers is frequently impracticable because of lack of medical personnel.

In the medical inspection of a group or unit for the presence of suspects, care should be taken that all members of the group or unit are seen by the examining medical officer. In large units, the examinees should be checked from a roster. Otherwise, some of those who are sick will, for one reason or another, fail to report for examination. Particular attention should be devoted to the detection of those who present only mild symptoms of the disease in question.

As a substitute for, or in addition to, daily medical inspection, unit commanders should, in the presence of an epidemic, be directed to send to the hospital or dispensary any member of their commands who presents any evidence of being ill, even if the symptoms are mild and apparently unimportant. Where the intelligent cooperation of unit officers and noncommissioned officers can be obtained, this procedure will

result in a considerable number of the cases being removed from contact with other members of the unit before they have had an opportunity to spread the infection.

Personal hygiene. Promiscuous sneezing, coughing and expectorating, or uncleanliness of the hands, the use in common by two or more persons of articles such as towels, drinking cups and eating utensils, are important factors in the transference of infected discharges from the respiratory tract. Good personal hygiene on the part of the troops will reduce both air-borne and hand to mouth transmission of the infective agents of respiratory diseases. The extent to which the rules of personal hygiene can be enforced in a command depends to a considerable degree on the discipline and training of the troops, and the enforcement of such rules can be obtained only through the cooperation of unit officers and noncommissioned officers.

In the presence of epidemics of respiratory diseases, or wherever measures for the control of respiratory diseases are indicated, special stress should be placed on personal hygiene. All troops should be instructed relative to the importance of personal hygiene, and particular attention should be given by medical officers to the instruction of officers and noncommissioned officers in order that their cooperation in the enforcement of personal hygiene regulations may be obtained.

Food, dishes and eating utensils. Infected discharges from the respiratory tract may be transferred in food, on dishes, or on eating or drinking utensils. Food, especially that which has been prepared and is ready to serve, may be infected by food handlers who have, or who are carriers of a respiratory disease. The routine periodic physical examination of food handlers should include examination for respiratory diseases. Further, it is very important that any food handler who exhibits any symptoms of a respiratory disease should be relieved at once from duty requiring him to handle the food of others (Chapter XII).

The water in which mess kits, dishes and eating utensils are washed, or the cloths used to dry them, may serve as means of indirectly transmitting the causal agents of respiratory diseases. All mess equipment should be disinfected by steam or by washing in boiling or hot soapy water, or with

chlorine, and should be air dried where practicable (Chapter XII).

Exercise. Moderate exercise in the open air is a valuable aid in the control of the spread of respiratory infections among troops. This measure serves not only to promote the physical fitness and morale of the individual, but also reduces crowding indoors. As a general rule, in the presence of an epidemic of a respiratory disease, troops should be kept busy out of doors for as much time each day as the weather will permit.

As far as practicable, advantage should be taken of every opportunity to afford exposure to sunshine. Apparently, sunshine and exercise will reduce the carrier incidence or shorten the carrier period in the individual, and thus decrease the exposure rate.

Fatigue and chilling. Fatigue and chilling will, in many instances, lower the resistance of the individual to respiratory diseases. In the presence of epidemic conditions which are serious or threaten to become serious, all work which would result in excessive fatigue or exhaustion should be reduced to a minimum. In order to prevent unnecessary chilling of the body surface, exposure of troops to inclement weather should be avoided as far as practicable, and all men should be provided with and required to use warm clothing and bedding.

Concurrent and terminal disinfection. Concurrent disinfection should be practiced in the care of all cases of respiratory disease. The discharges from the respiratory tract should be burned or disinfected with a chemical disinfectant. Ordinarily, the patient should not use dishes or eating utensils that are used by others. All articles, such as thermometers, wash basins, bedpans or urinals, used in common in the care of patients, should be disinfected after use.

Medical officers, nurses and enlisted attendants should exercise care that infected discharges are not transferred from patient to patient by the hands or clothing. The hands should be washed with hot soapy water after each contact with a case of respiratory disease. A gown should be worn to protect the clothing from contamination. If practicable and indicated, a separate gown should be worn for each case.

Face masks have not been found to be effective in preventing the transmission of respiratory diseases.

The causal agents of respiratory diseases, as a group, are readily destroyed by exposure to sunlight, by drying, or by soap and water. Consequently, terminal disinfection can usually be satisfactorily accomplished by the thorough airing or sunning of the bedding and by scrubbing the floors and the beds or cots with hot water and soap. The bedding may be disinfected in a steam disinfector.

Fumigation is not an effective procedure for terminal disinfection.

MEASLES
(*Rubeola*)

Definition. Measles is an acute infectious disease which is manifested clinically by fever, catarrhal inflammation of the upper respiratory tract, and a characteristic eruption.

Etiology. The etiological agent of measles is considered to be a filterable virus, although a number of different organisms have been incriminated as causal agents by various workers. The virus is present in the buccal and nasopharyngeal secretions.

Incubation period. The incubation period from exposure to the beginning of the period of invasion, as indicated by the occurrence of prodromal symptoms, is from eight to ten days. The period from the date of exposure to the appearance of the exanthem is, in the vast majority of cases, from twelve to fourteen days. Rarely, the incubation period may be as long as eighteen days. When convalescent or immune adult blood (*infra*) has been administered, the incubation period may be prolonged to twenty-one days.

The incubation period of measles is remarkably constant, so much so that the quarantine period for contacts may be definitely limited to fourteen days. The constant character of the incubation period is probably the result of the uniformly high infectivity of the disease. If the characteristic measles rash does not appear fourteen days after a known and definite exposure to infection, it may be assumed that the exposed person is immune to, and will not transmit the disease. As the prodromal symptoms are at times difficult to diagnose and may be transi-

ent and escape detection, it is not safe, under ordinary conditions, to limit the quarantine of contacts to the ten-day incubation period prior to the invasion.

Transmission. In the transmission of measles, the source of infection is the case in its prodromal or fully developed stages. Healthy carriers are not known to exist and the infection is not transmitted by convalescent carriers. The infective agent of measles is transferred from person to person in the discharges from the nose and mouth. The infected secretions are transmitted by air, and it is probable that, in many instances, transmission is also effected by contact through the medium of contaminated articles and the hands.

Because of the high degree of susceptibility of a non-immune individual and the small dose of the virus required to produce infection, only the slightest and most transient contact is required to transmit the disease. Any one of the numerous articles which might be handled by or exposed to the exhalations of an infected person, such as papers, books, door knobs, furniture, mess equipment, or food, may serve to transfer the infection directly to the mouth, or to the hands and hence to the mouth or nose, of another person.

The period of communicability begins definitely with the appearance of catarrhal symptoms and terminates with the cessation of abnormal secretions from the mucous membranes. As catarrhal symptoms appear about four days before the eruption and usually do not cease until a minimum of five days thereafter, the minimum period of communicability is nine days. The catarrhal symptoms may, however, persist for a longer period of time with a corresponding increase in the length of the period of communicability. It is probable that occasionally the causal agent is transmitted before the appearance of the prodromal symptoms.

Susceptibility and immunity. Man is universally susceptible to measles. Susceptibility is not influenced by age after the first few months of life, nor by race, season or geographical location. One attack of measles confers a permanent immunity. It is possible that second attacks may occur but they are rare and the belief that a second attack has occurred is often based on a mistake in diagnosis.

Prevalence and importance. Measles occurs most frequently during childhood and, in general, the great majority

of persons acquire immunity before reaching adult life. In densely populated communities the exposure rate is relatively high and few escape infection during the early years of life. In rural districts, where the opportunities for exposure are less numerous, a correspondingly greater proportion of the population attain adult life without having had the disease. Consequently, troops drawn from rural districts have a much higher group susceptibility to measles than those recruited from urban communities.

Measles is especially prone to occur in epidemic form during the early days of mobilization, and epidemics of measles may constitute a serious handicap to the rapid mobilization and training of troops. The crowding and overcrowding which almost inevitably accompany rapid mobilization, together with the likewise inevitable induction into organizations of susceptible and infected men, produce conditions under which epidemics of measles can be controlled only by the most energetic enforcement of suitable measures.

A measles epidemic is not ordinarily so explosive in character as epidemics of influenza or common colds. This is due to the comparatively long incubation period and the resulting interval between the occurrence of primary and the development of secondary cases. However, while the progress of an epidemic of measles may be, and frequently is, retarded during its early stages, it spreads rapidly with the appearance of secondary and tertiary cases and may then assume an explosive character among troops having high group susceptibility. This delay in the spread of a measles epidemic during its early stages is an important factor in the control of the disease.

During the World War, the admission rate for measles was 23.79 and the noneffective rate 1.25 per thousand strength. There were 96,817 admissions and 2,367 deaths. Measles caused a loss from duty of 1,864,477 days by about 4,000,000 troops.

Control measures. The control of measles is based on the control of cases and contacts as sources of infection. Generally, prompt removal of cases and suspects from contact with other members of the command, together with group quarantine of close contacts and the employment of the general measures for the control of respiratory diseases, is the most practical method of limiting the spread of the disease or retarding the progress of an epidemic. Where conditions per-

mit, the passive immunization of susceptible contacts with convalescent or adult serum or whole blood is a valuable control measure (*infra*).

When a case of measles occurs in an organization, the close contacts of the case should be placed in group quarantine (page 23). The troops in quarantine and, if practicable, the entire command or the company to which the case and the contacts belong, should be examined daily by medical officers for the prodromal symptoms of measles.

Group quarantine may be employed in the control of measles as a working quarantine of close contacts or in connection with the general detention or quarantine of recruits (page 25). Group quarantine of close contacts will, when successful, limit the occurrence of secondary cases to the quarantined group and thus protect the remainder of the organization from the disease.

Group quarantine for measles should continue for fourteen days subsequent to the removal of the primary case, or after the removal of the last secondary case should secondary cases occur within the quarantined group. If secondary cases occur outside the quarantined group, the close contacts of these cases should be placed in working quarantine. Should a second crop of secondary cases, or tertiary cases, occur, the disease is usually then so widespread through the organization that group quarantine of the close contacts of each case will no longer influence the spread of the disease.

Physical examination for prodromal symptoms. The hospitalization of cases during the early part of the prodromal stage limits the dispersion of the causal agent and delays the spread of the disease through the command. The prodromal stage is manifested by catarrhal symptoms, fever, headache which is usually frontal in character, malaise and eruption (enanthem and Koplik spots) on the mucosa of the mouth and throat. As occasionally the prodromal symptoms may be transient and fugitive, the physical examination should include an inspection for the measles rash.

The catarrhal symptoms are the most characteristic manifestations of the prodromal stage of measles. They consist of sneezing, hypersecretion from the nasal membranes and at times pain and soreness of the throat and mild bronchitis. There is inflammation of the ocular conjunctiva which may be accompanied by a more or less well marked photophobia. In a typical

case, the catarrhal symptoms appear at the beginning of the period of invasion and continue throughout the prodromal stage. They become accentuated with the development of the rash and usually subside as the rash fades.

Fever is generally a well marked prodromal symptom, and, as a rule, some fever is present from the onset until after the eruption is completely developed. It may rise to a peak during the first day or two of the period of invasion and then remit and again rise with the appearance of the rash.

The enanthem and Koplik spots are forerunners of the exanthem. They generally appear during the second or third day of the period of invasion, that is, a day or two before the appearance of the exanthem, or skin rash. Both the enanthem and the Koplik spots are of diagnostic value, especially in the presence of catarrhal symptoms.

In a typical case, the skin rash appears on the fourth day; in other cases on the third or possibly on the fifth day of the disease. It consists of small, red, macular and later papular spots which as a rule appear first on the sides of the face, forehead and sometimes behind the ears. Subsequently, the rash spreads to other parts of the body.

In the presence of measles, any person who exhibits any of the prodromal symptoms of the disease should be regarded as a suspect and hospitalized, regardless of whether or not he is known to have been in contact with a case of measles, unless it is definitely known that he has had measles.

Officers and noncommissioned officers with the quarantined group or unit should be instructed to send at once to the hospital any man who shows symptoms of coryza or complains of illness.

Separation of susceptibles and immunes. As an attack of measles confers permanent immunity, and as an exposed immune person will not become a healthy carrier of the infection, it may be practicable, under certain conditions, to separate the susceptible persons from those who are immune to the disease. It may, for example, be desirable to remove immune men from quarantine as contacts or to select immune hospital attendants for work with measles cases. In other instances, susceptible individuals may be segregated so that special precautions may be taken to protect them from infection or to prevent those who have been exposed from spreading the infection. If passive immunization is to be used as a control measure, then those susceptible to in-

fection must be separated from those who have had the disease.

Immunity to measles can be determined only by the individual medical history. There is no skin test or serological reaction which is indicative of immunity. However, where there is a definite history of an attack of measles, the individual can be regarded as immune to the disease, although this method of determining immunity is subject to considerable error. Moreover, the error in the greater proportion of instances tends to indicate that the individual in giving his history may honestly believe that he has had measles when such belief is actually based on a mistaken diagnosis or vague information. Also, in the presence of a measles epidemic, a certain number of men will allege that they have had measles in order to escape quarantine or to avoid the injection of immune blood or serum. If susceptible contacts who are wrongly assumed to be immune to measles are released from quarantine or otherwise escape control, they will probably serve as sources of infection. An individual should be assumed to be susceptible in all instances where there is any doubt or question as to the occurrence of a prior attack of measles.

Immunization. Passive immunity may be conferred by the use of convalescent or adult serum or whole blood. In the preparation of convalescent serum, blood is obtained from convalescent measles patients from five to thirty days, preferably within fifteen days, after defervescence of the fever. The blood is drawn in the usual manner and the serum is separated. Citrated whole blood may be used and is equal to the serum in potency if larger doses are used (*infra*).

Convalescent serum is injected intramuscularly in doses ranging from five to ten c.c. for children to thirty c.c. for adults. Where whole convalescent blood is used it should be administered in doses of from ten c.c. for small children to sixty c.c. for adults. Larger doses should be employed if administered late in the incubation period.

Adult whole blood or serum obtained from individuals who had measles a number of years previously can also be used to confer passive immunity. Adult blood is but slightly less effective than convalescent blood in producing immunity, and it is usually more readily obtainable.

Adult whole blood or serum is injected intramuscularly in doses which are from 50 to 100 per cent larger than the doses of

convalescent whole blood or serum. Sixty to eighty c.c. of adult whole blood, or thirty to forty c.c. of adult serum, should be used in the immunization of adults. One-half of these amounts should be given to children under six years of age.

It should always be determined that the donor of either convalescent or adult blood is free from any disease which might be communicated by the blood, especially syphilis.

Serum, either adult or convalescent, may be obtained in quantity when available and preserved for future use by drying. Dried serum will retain its potency for a relatively long period of time, probably for several years.

If serum or whole blood, either adult or convalescent, is administered during the first five days after exposure to measles it will usually prevent an attack of the disease. If employed during or after the fifth or sixth day of the incubation period, and prior to the onset of the disease, the serum or whole blood will not usually afford complete protection from the disease but will, as a rule, modify the severity of the attack. If given after the onset, it exerts no apparent influence on the course of the disease. If the dosage is too small the occurrence of the disease will not be prevented, even though administered before the fifth day of the incubation period, but the attack will usually be less severe.

According to the observations made by various workers, the immunity conferred by convalescent or adult serum or whole blood persists for about six weeks and will afford some degree of protection for as long as six months.

Immunization with immune serum or whole blood can be used to protect susceptible contacts in group quarantine or as a control measure in lieu of group quarantine. It is of particular value as a control measure where a primary case has been detected and there are no other sources of infection present. Immunization may also be of decided value in the prevention of measles epidemics among the troops and other passengers aboard transports.

The principal disadvantage of immunization as a control measure is the difficulty of obtaining convalescent or adult blood in quantities sufficient to immunize large numbers of troops. Also, during mobilization large numbers of recruits susceptible to measles, together with measles contacts and possibly cases of measles, are constantly being introduced into the command and

it may be necessary to repeat the injections at intervals of from one to three months as long as there is danger of exposure to infection. Nevertheless, despite these disadvantages, immunization with immune serum or blood is a valuable control measure in reducing the noneffective rate due to measles.

Control of measles among children. Owing to the danger of pneumonia every effort should be made to control the spread, or to prevent the occurrence, of measles among the children of a military garrison. Susceptible children who have been exposed to infection should be immunized with convalescent or adult whole blood or serum. Even if administered late in the incubation period, immune blood or serum will lessen the severity of the attack and decrease the danger of pneumonia. Usually, immune blood can be obtained from one of the parents.

The immune children of a family in which a case of measles has occurred may continue to attend school, but the susceptible children should not attend school and should be isolated from all contact with other susceptible persons.

Complications. Measles complications are apt to be more prevalent among troops than in civilian communities, due largely to the fact that in a military force all measles cases must be treated in hospital with a consequent increase in exposure to cross infections.

Pneumonia is the most frequent complication of measles, while otitis media ranks second in prevalence.

The pneumonia following measles is usually bronchopneumonia, although the lobar type may occur. The case fatality rate is relatively high. During the World War, the case fatality rate for bronchopneumonia following measles was thirty-five per cent.

The prevention of pneumonia among measles patients is based on early hospitalization, with as little subsequent movement as possible, and protection from cross infections. Pneumonia is a secondary infection to which measles predisposes and the measles patient should, therefore, be protected from secondary infection both during the course of the disease and for from ten days to two weeks after the temperature returns to normal (page 60). Where practicable, ample floor space, at least one hundred square feet, should be provided for each patient in measles wards. Each patient should be protected by a cubicle screen (page 33).

Exertion on the part of the measles patient apparently lowers his resistance to secondary infections and augments the danger of pneumonia. He should be kept quiet in bed during the course of the disease and no excessive exertion permitted until the temperature has been normal for from ten to fourteen days.

Disinfection. The measles virus is short lived and is readily destroyed by disinfectants or by sunlight and drying. A squad room in which a case of measles has occurred can be disinfected by airing or by scrubbing the floor with soap and water. The bed or cot occupied by the patient should be washed with hot soapy water. The bedding and mattress should be aired, and sunned if the weather is suitable.

Thorough concurrent and terminal disinfection should be practiced in the care of measles cases in hospitals, not only to prevent the transmission of the measles virus to susceptible persons, but also to protect the measles patients from secondary infection with the causal agents of pneumonia (page 39).

INFLUENZA

(Epidemic influenza, Grippe, La grippe)

Definition. Influenza is an acute, highly infectious disease, characterized clinically by sudden onset, fever, myalgia, respiratory symptoms, prostration and a tendency toward the development of severe pulmonary complications.

Etiology. The etiological agent of influenza is now generally considered to be a filterable virus, of which there are several, or possibly a large number, of strains. Recently a number of investigators, including Smith, Andrewes and Laidlaw, Francis, Shope, and others, working with experimental animals, principally ferrets, mice and swine, have been able to demonstrate that certain strains of human influenza virus produce constant characteristic changes in animals, and that recovered animals are immune to infection. However, it has not been definitely proven that a filterable virus is the sole etiological agent of human influenza. There is some evidence indicating that *Hemophilus influenzae* (Pfeiffer's bacillus) is in some way associated with the etiology of influenza.

A number of different bacteria have been incriminated as secondary invaders and the causative agents of some of the clin-

ical manifestations and complications of the disease.

The infective agent is contained in the discharges from the nose and throat.

Incubation period. The incubation period of influenza is short and variable. It usually lasts from 24 to 48 hours but may be as long as four days.

Transmission. Influenza is a typical contact disease. It is carried by the infected person and because of its high infectivity it is transmitted by very slight and transient contact. It is probable that the transference of the infection directly from person to person by droplet infection is a most important factor in the transmission of influenza, but transference of the causal agent by inanimate objects and hand to mouth infection also plays an important role in the spread of the disease. Eating utensils and food that have been contaminated with the infective agent are important factors in the transmission of influenza.

Influenza is probably transmissible throughout its clinical course, but it is generally considered to be most infectious during the period of invasion and the early stages of the disease. The rapid spread of the infection is greatly facilitated by persons who, though they have influenza in a mild form, do not go to bed and are not isolated or segregated, or at least not until after the disease is fully developed.

The existence of healthy carriers of influenza has not been proven, but if they do exist, they are probably of little importance in the spread of the disease.

Prevalence and importance. The clinical manifestations of influenza are complex, and a mild form of the disease is difficult to differentiate from the mild respiratory infections or common colds. If, and when, influenza occurs endemically, or with mild epidemicity, it is apt to pass undiagnosed until a mounting sick rate, or an increasing incidence of pneumonia, calls attention to its presence by indicating that some unusual respiratory infection is prevalent.

Influenza tends to occur in pandemic cycles consisting of primary and secondary waves. Pandemics and epidemics are characterized by extreme explosiveness and rapidity of spread. A typical epidemic sweeps rapidly through a military organization, the majority of cases occurring within a

short time after its introduction. In civil life, the infection follows the lines of travel at the speed of travel.

Influenza attacks all ages, but is most fatal in the 20 to 40 year age group. It occurs during all seasons of the year, but most frequently during the colder months of the year.

Influenza, like other respiratory diseases, is generally less prevalent among troops from urban districts than among those drawn from rural sections of the country, although this difference is not so marked as in the case of diseases such as measles and mumps. It is probable that the higher resistance of urban troops is due to a nonspecific immunity conferred by more frequent prior contacts with respiratory infections.

The incidence of influenza also tends to be greater among recruits, or men who have had only short service, than among trained and seasoned troops. This is due in all probability to the greater nonspecific resistance of the trained men to respiratory infection (page 30).

Pandemic influenza or extensive epidemics of the disease interfere seriously with military operations or the training of troops. The explosiveness of the epidemic and the rapidity with which the infection spreads through a command frequently so cripple an organization that it will, as a whole, become noneffective for the time being. However, the very explosiveness and rapidity of spread also serve to render influenza epidemics short lived, and a military organization recovers from the effect of an epidemic within a comparatively short time.

Immunity and susceptibility. It is generally considered that an attack of influenza confers only temporary immunity of variable duration, and only to the particular strain of the virus causing the attack. Susceptibility is determined largely by the nonspecific immunity to respiratory infections which may be possessed by the individual at the time of exposure to infection. There is no method available by which immunity to influenza can be artificially conferred. Various vaccines have been studied but so far have been found to be of little practical value in the immunization of large numbers of troops. The recent work with human influenza virus in experimental animals (*supra*) promises to lead to the development of a specific vaccine.

Control measures. The explosive nature of influenza epidemics and the rapidity with which the disease spreads through an organization greatly reduce the effectiveness of all control measures. However, even though control measures may not be effective in reducing materially the ultimate incidence of the disease, much can be done to retard the spread of the infection. If the rapidity of spread is reduced there will be less interference with military activities and the demand on the hospital facilities will not be so great (page 31).

When cases of influenza appear in a command, or when the disease is known to prevail elsewhere and its appearance among the troops is anticipated, all close contact should be reduced to a minimum. The maximum bed space available should be allotted in barracks or tents, and cubicles should be used when practicable. In theaters, only alternate seats and alternate rows should be utilized. The troops should be instructed relative to the dangers attendant upon crowding together in day rooms and elsewhere. All close order drill and similar military formations that are not absolutely necessary should be discontinued for the time being. Crowding in mess halls and at mess tables should be avoided or minimized. A canvas or board partition may be installed along the center line of a mess table as an aid in preventing dissemination of the causal agents. Special attention should be given to the thorough disinfection of all mess equipment and eating utensils. Food handlers should be observed and supervised constantly to the end that no individual in the incubationary or early stages of the disease is allowed to contaminate the food or the mess equipment (Chapter XII).

Group quarantine is of little or no practical value in the control of influenza. Theaters, service clubs, libraries or other recreational facilities should not be closed except under the most extreme conditions. Measures can be taken to control crowding in these places, but if they are closed the troops will crowd together in other places where they cannot be so readily controlled.

Medical examination. Prompt hospitalization of cases during the early stages of the disease will reduce the opportunities for the dissemination of the infection and will improve the prognosis of the individual case. Where practicable, troops should be examined daily by medical officers for the

purpose of detecting those who present symptoms of respiratory infections. At times, however, in the presence of an influenza epidemic, the demands made on the medical personnel are such that medical officers are not available for making daily examinations of large bodies of troops. Under such conditions, officers and noncommissioned officers should be instructed to report at once to the proper medical authority any and all men of their organizations who show any indications of illness.

Complications. Pneumonia is the most common and by far the most important complication of influenza. Influenza alone is seldom fatal, the influenzal mortality being almost entirely due to pneumonia. During the World War, among 4,000,000 American troops, there were 783,895 admissions for influenza, with 24,575 deaths. Over 99 per cent of the deaths were due to a complicating pneumonia, either bronchopneumonia or lobar pneumonia.

The prevention of influenzal pneumonia is based mainly on maintaining the resistance of the patient and preventing infection with the causal agents of pneumonia.

Exertion and chilling are important factors in the development of pneumonia. It is especially important that the transportation of patients for long distances be avoided. The patient should be put to bed as promptly as possible after the development of the invasional symptoms. He should be kept warm and the ward should be well ventilated at all times.

In the hospital, the same procedures should be employed to prevent secondary infection as in the care of measles cases (pages 39 and 48).

COMMON COLDS

(*Acute coryza, Common respiratory diseases*)

Definition. The diseases which are grouped for control or statistical purposes as common colds or common respiratory diseases consist of acute rhinitis, together with acute tonsillitis, pharyngitis, laryngitis and bronchitis. Generally, they are characterized clinically by localized, or in some instances, general catarrhal inflammation of the upper respiratory tract and, in the more severe forms, by fever, headache, malaise and prostration.

Severe or moderately severe forms of a common cold are difficult to differentiate from mild influenza. During the early stages of an influenza epidemic, the disease is frequently considered to be and is diagnosed as coryza, bronchitis or some other common inflammatory condition of the upper respiratory tract until the occurrence of severe cases and the increasing incidence of pneumonia reveal the true nature of the infection.

Etiology. The etiological agent, or agents, of common colds, including the accompanying rhinitis, nasopharyngitis, pharyngitis and laryngitis, have not been definitely determined. While a number of organisms have been described as the etiological agents of common colds, none has been proven to be the cause of the disease in all instances. There is now much evidence that common colds are primarily due to a filterable virus, or a group of filterable viruses. However, streptococci, pneumococci and various other organisms are found associated with tonsillitis and bronchitis and may, in some instances, be the causal agents of these conditions, or they may be secondary invaders following or accompanying infection with a filterable virus.

The conditions which lower the local resistance to infection are undoubtedly factors in the etiology of the common colds. Chilling, fatigue and local circulatory disturbances due to poor air conditions facilitate invasion of infective agents pre-existing on the mucous membranes of the nose and throat, or of those acquired by exposure to sources of infection. Protein sensitization may be an etiological factor in some instances.

Incubation period. The incubation period of a common cold is, in many instances, difficult to determine, but is usually from one to three days.

Transmission. Common colds and the accompanying inflammatory conditions of the upper respiratory tract are spread from person to person by contact. Epidemiological studies indicate that the causal agents are transferred in the discharges from the nose and throat by droplet infection, by hand to mouth transmission, and by inanimate objects. Mess equipment or food which has been contaminated by infected secretions may serve to transmit the infection. As a rule, the case is the source from which the infection spreads although,

undoubtedly, there are carriers of the etiological agents who also serve as sources of infection.

Susceptibility and immunity. Susceptibility to common colds is universal. An attack usually confers some degree of temporary immunity which may persist for several months. No method has been found as yet by which immunity to common colds can be artificially conferred.

Resistance to infection is apparently increased by improvement in general physical fitness, and trained troops are less susceptible to colds than are recruits.

Prevalence and importance. Common colds are usually characterized by high infectivity and are most infectious during the early stages of an attack. These factors, together with the absence of immunity, and the close association among individuals in a military organization, tend to produce sharp epidemics of an explosive nature.

Common colds are more prevalent during cold or changeable weather. Apparently, exposure to inclement weather lowers the resistance to infection, and the troops tend to congregate in squad rooms and day rooms, with the result that the crowding facilitates the transference of infected nasopharyngeal secretions. Also, the difficulty encountered in properly ventilating barracks and tents during cold weather is a factor in lowering the resistance of the individual to infection. Apparently, neither nativity, age nor race affects the prevalence of these infections to any considerable extent.

Common colds *per se* are of great importance in military preventive medicine, not only because of their temporary disabling effect and their influence on the noneffective rate, but also because they are important factors in the spread of other respiratory diseases. The coughing and sneezing, with the consequent general increase in the discharge of nasopharyngeal secretions which accompanies an attack of coryza, serve to facilitate the dissemination of the infective agents of other diseases, such as pneumonia, measles, mumps or meningococcic meningitis. For this reason, an epidemic of common colds is especially dangerous among recruits.

Control measures. In order to be most effective, measures for the control of common colds should be applied in anticipation of the occurrence of epidemics, as the rapid spread of the infection after an epidemic begins frequently

renders current control measures of little practical value.

There are no specific measures for the control of common colds. A number of vaccines have been developed but none has proven to be effective.

Of the general control measures, those designed to control contact and provide for the proper ventilation of squad rooms are of the most value (Chapter IV). Undue chilling or fatigue should be avoided, especially in the case of recruits (page 39). In cold weather, troops should be supplied with ample warm clothing and blankets. The troops should be trained to avoid promiscuous sneezing, coughing and expectoration when in the vicinity of others.

Good mess sanitation is an important factor in the control of the common respiratory diseases. No food handler who presents symptoms of a respiratory disease should be permitted to remain on duty requiring him to handle the food of others. All eating and serving utensils should be properly disinfected to prevent the transmission of the causal agents (Chapter XII).

PRIMARY LOBAR PNEUMONIA

Definition. Primary lobar pneumonia is an acute infectious disease manifested clinically by exudative inflammation of the lungs, fever, pain in the affected area, and a characteristic rusty sputum.

Etiology. Primary lobar pneumonia is, as a rule, due to invasion by some one type of pneumococcus. Rarely the disease may be caused by other organisms such as streptococcus, Friedlander's bacillus or Pfeiffer's bacillus. Primary lobar pneumonia, is not, strictly speaking, a disease entity, but rather the term is applied to a group of diseases each of which is due to a specific type of pneumococcus.

Pneumococci are classified into thirty-two types. Until recently Types IV to XXXII, inclusive, were classified as Group IV. This classification is based on the serological reactions of the organisms and is important in both the control and the treatment of the disease.

The relative proportion of pneumonia due to each of the types of pneumococci varies in different age groups, in different geographical sections, and also from year to year in the

same locality. In the United States, generally, Type I is the etiological agent in from 20 to 35 per cent, Type II in from 20 to 30 per cent, Type III in from 12 to 15 per cent, and Types IV to XXXII, as a group, in from 20 to 40 per cent of all cases of primary lobar pneumonia.

Incubation period. The incubation period of primary lobar pneumonia has not been definitely determined but is usually considered as being quite short and variable. It is probably from 24 to 72 hours in most instances.

Transmission. Pneumococci are transferred from person to person in the discharges from the respiratory tract. Pneumonia may be transmitted either by the person having the disease or by carriers of the causal organisms. The pneumococci carrier incidence is relatively high and, in most instances, the person contracting pneumonia has been infected by a carrier. Lobar pneumonia ordinarily occurs as sporadic cases, although the disease may assume epidemic prevalence under especially adverse conditions with regard to crowding, chilling and fatigue. Usually the infection cannot be traced from case to case.

Carriers of Types I and II pneumococci are usually either convalescent carriers, or healthy carriers who have acquired the organisms through more or less direct contact with a case of pneumonia. Carriers of Type III are more numerous than carriers of either Type I or II, but pneumonia due to Type III organisms is considerably less prevalent than that caused by Type I or Type II. Carriers of other types of pneumococci are comparatively numerous, but the organisms of which this group is composed have comparatively low virulence.

Pneumonia due to Types I or II is not usually the result of autogenous infection, but is caused by infection from without. Where the infection is caused by Type III pneumococci, or some one of the other types, the organisms may have been carried in the mouth or throat for some time prior to the development of the disease. Consequently, where lobar pneumonia is due to Types I or II, the infection is not ordinarily transmissible prior to the onset of clinical symptoms, but where the disease is the result of an autogenous infection with one of the other types, the patient is capable of transmitting virulent organisms for varying periods of time before the disease develops. Subsequent to recovery from the disease the

organisms usually disappear from the mouths and throats of convalescent carriers within a short period of time, generally in less than 30 days.

The transmission and wide distribution of the causal agents of primary lobar pneumonia are facilitated by epidemics of coryza or common colds and the consequent coughing and sneezing, even though the pneumonia is not secondary to such infections.

The pneumococcus is easily killed by an adverse environment outside the body, although it may survive for long periods in dried discharges from the respiratory tract. Ordinarily, however, the organisms are transmitted in the fresh secretions from the respiratory tract by droplet infection, on the hands, or by inanimate objects.

Susceptibility and immunity. One attack of pneumonia apparently confers temporary immunity, but recurrences are relatively common. However, it is probable that, in many instances, recurrences are caused by organisms of a type different from those which caused the primary attack.

The mechanism of immunity to lobar pneumonia has not been fully determined. Theoretically, man should be universally susceptible but actually, in an average environment, group susceptibility to the disease is comparatively low. Individual susceptibility may, however, be augmented by fatigue, chilling, or other respiratory diseases which would tend to lower the general resistance to infection.

Prevalence and importance. The prevalence of primary lobar pneumonia tends to be endemic or sporadic rather than epidemic. Geographically, the distribution of pneumonia is world wide. The seasonal incidence varies, but the disease tends to be more prevalent during the winter and spring months. Lobar pneumonia attacks all races, but the incidence and case fatality rates are higher among negroes than among members of the white race.

From a strictly military viewpoint, primary lobar pneumonia is not, under ordinary conditions, an important disease, as its low incidence and the fact that it seldom assumes epidemic prevalence preclude any considerable interference with military activities. However, primary lobar pneumonia may occur with localized epidemic prevalence among troops when the environmental factors are such as to lower the group re-

sistance to infection. Continued exposure to inclement weather, undernourishment, lack of adequate shelter, and crowding together with the consequent increase in the prevalence of common respiratory diseases under such conditions will frequently result in a marked increase in the prevalence of primary pneumonia.

Control measures. The prevention of primary lobar pneumonia depends not only on the control of transmission but even to a greater degree on the maintenance of group resistance to the disease. The procedures employed for the control of the common respiratory diseases will, by restricting the spread of these diseases, afford a degree of protection against lobar pneumonia by limiting the distribution of pneumococci (page 54). Moreover, it is probable that a great many of the cases of so-called "primary" lobar pneumonia are actually secondary to acute coryza. Special attention should be given to the prevention of overcrowding during cold weather, particularly when coryza or other respiratory diseases are prevalent.

Under actual conditions with troops, the principal factors to be considered in the prevention of lobar pneumonia by maintaining group resistance are adequate shelter, proper food, suitable clothing and bedding, and the avoidance of long continued exposure to cold or wet weather and duties which will cause undue fatigue.

Where a case of primary lobar pneumonia occurs in an organization, the patient should be isolated in hospital. Group quarantine of close contacts has not been found to be effective in preventing the occurrence of other cases. Whenever practicable, those who are convalescent or have recovered from an attack of pneumonia should be retained in quarantine in hospital until the carrier state disappears.

Active immunization. Various type specific vaccines have been developed which will confer active immunity to infection with pneumococci in experimental animals. Cecil and Austin in one instance, and Lister in another, have shown that the prevalence of primary lobar pneumonia among large groups of persons can be controlled by active immunization to specific types of the organism.

The work of Felton with an antigen consisting of the soluble specific substances of Type I and II pneumococci has given

promising results. A pneumonia vaccine containing the specific soluble substances of Type I and Type II pneumococci, and made in accordance with the procedure and technique developed by Felton, is manufactured and issued by the Army Medical School. The vaccine is prepared by precipitating the bacterial polysaccharides and dissolving the dry precipitate in salt solution. One dose of the vaccine contains one-half milligram of the Type I precipitate and one-half milligram of the Type II precipitate dissolved in either one-half c.c. or one c.c. of salt solution. The vaccine is injected subcutaneously and only one dose is given.

The immunizing value of a vaccine containing the specific soluble substances of pneumococci has not been fully determined, but the results of the studies that have been made indicate that some protection against pneumonia is conferred. Theoretically, vaccination with this vaccine should be repeated once each year.

Vaccines containing the specific soluble substances of types of pneumococci other than Type I and II have been studied by different workers, but the results have been inconclusive.

Disinfection. Concurrent and terminal disinfection should be practiced in the care of pneumonia patients in hospital, with particular attention to the destruction of all discharges from the nose and mouth. In general, the measures described on page 39 should be employed.

SECONDARY PNEUMONIA

Pneumonia frequently occurs as a complication or sequela of other acute respiratory diseases, particularly measles, influenza and acute coryza (common respiratory diseases). Secondary pneumonia may be either lobar pneumonia or bronchopneumonia, but the latter predominates. The causal agents are usually either the pneumococcus or *Streptococcus hemolyticus*, but secondary pneumonic conditions may be due to other organisms, such as staphylococcus or Pfeiffer's bacillus. In the majority of instances, bronchopneumonia is caused by *Streptococcus hemolyticus*.

Practically all of the deaths due primarily to influenza are caused directly by complicating pneumonia. During the World War, 99 per cent of the deaths charged to influenza were directly due to pneumonia and of this total 66 per cent were re-

corded as due to bronchopneumonia and 33 per cent to lobar pneumonia.

Uncomplicated measles is seldom, if ever, a fatal disease in adults and the greater proportion of the deaths attributed to measles are the direct result of a complicating pneumonia. There were 3,206 deaths reported as occurring among the 92,225 cases of measles admitted to hospital during the World War. A number of these deaths were due to concurrent disease unrelated to measles, but 2,186 or 68 per cent, were recorded as caused by pneumonia. Of the total number due to pneumonia, 72.5 per cent were caused by bronchopneumonia and 27.5 per cent by lobar pneumonia.

Control measures. The control of secondary pneumonia is principally a question of controlling the primary disease. Nevertheless, the incidence of pneumonia secondary to influenza and measles can be materially reduced by suitable control measures.

In dealing with epidemics of influenza or measles, the measures to be taken to prevent the occurrence or to reduce the incidence of secondary pneumonia are just as important, if not more so, than are those concerned with the control of the primary disease. The prevention of secondary pneumonia will reduce the noneffective rate due to prolonged hospitalization and will save many lives.

The maintenance of group and individual resistance to infection before and after the onset of influenza or measles is an important factor in the prevention of secondary pneumonia. In the presence of an epidemic of influenza or when susceptible troops are exposed to measles, all possible precautions should be taken to protect the exposed groups from chilling or wetting. If the epidemic occurs during cold weather additional clothing and blankets should be provided if needed. Activities which would cause undue fatigue should be avoided or reduced to a minimum. Squad rooms or tents should be kept warm and well ventilated and the beds properly spaced (page 139). Additional attention should be given to the mess to insure that the troops receive proper and adequate food.

It is highly important in the prevention of secondary pneumonias that influenza and measles patients be put to bed promptly and kept there until convalescence is well estab-

lished. They should not be moved by being transferred from place to place in the hospital, or to another hospital. All individuals presenting suspicious symptoms, however mild they may be, should be hospitalized as a precautionary measure, or if hospital facilities are not available for all such cases, they should be required to remain in bed in their quarters until the diagnosis can be made.

The patients in hospital should be protected from all sources of secondary infection with pneumococci, streptococci, or the other organisms that might cause secondary pneumonia. Extraordinary care should be exercised to prevent the transmission of these infections from patient to patient, or from the hospital personnel or outsiders to the patients. It must be emphasized that the prevention of secondary pneumonias among measles or influenza patients requires that measles patients be protected from each other, or influenza patients from each other, even though they have the same primary disease, i.e., measles or influenza. For example, the measures taken to prevent the transmission of streptococci, pneumococci, or other organisms causing secondary pneumonia, from one measles patient to another should be much the same and as rigidly enforced as those employed to prevent cross infection between two patients each of whom has a different infectious disease. Complete individual isolation of each patient would be ideal, but this is seldom practicable. The beds should be separated by a space of at least five feet and all beds should be screened (page 33). Contact between the patients and any other person, except the doctors, nurses and attendants, should be scrupulously avoided. No visitors should be allowed. All hospital personnel who come into contact with influenza or measles patients should wear gowns. A gown worn while attending one patient should be changed before attending another, even though both patients have the same disease. All the other necessary precautions should be observed to prevent the transmission of infection from one patient to another by those caring for the patients. Masks are practically useless in preventing the transmission of organisms and may be a menace.

MUMPS
(*Epidemic parotitis*)

Definition. Mumps is an acute infectious disease characterized clinically by inflammation and swelling of the salivary glands, chiefly the parotid, but also at times the submaxillary and sublingual glands, and a tendency to involve other glandular structures, especially the testes, ovaries and the mammary glands.

The invasional period prior to the swelling of the parotid gland is short and variable. Glandular involvement may be, and frequently is, the first symptom observed. In other and more severe cases, prodromal symptoms, consisting of malaise, headache, fever, pain in the back and legs, and chilliness, may be present for from 24 to 48 hours prior to the onset of definite glandular involvement.

Etiology. The causative agent of mumps is unknown but is believed to be a filterable virus which is present in the saliva and probably also in the secretions from the throat and nose. It is also present in the blood.

Incubation period. The incubation period, from the date of exposure to the involvement of the parotid gland, varies from 14 to 26 days, but is usually considered as being from 16 to 21 days. For control purposes, 21 days may be considered as the maximum and 18 days as the average incubation period for mumps.

Transmission. The infective agent of mumps is transmitted by the air, by the hands, and, occasionally, by inanimate objects. Hand to mouth transference of the infected secretions is probably a most important factor in the transmission of mumps. The source of infection of mumps is usually a person having the disease in the fully developed or invasional stage. Mumps may, in some instances, be communicable during the incubation period before the occurrence of symptoms. The existence of carriers of mumps has not been definitely proven but it is probable that there are both healthy and convalescent carriers of the infection.

The period of communicability begins definitely with the onset of prodromal symptoms, or the glandular involvement, and continues until all swelling of the salivary glands has disappeared. In mild cases, the salivary glands return to nor-

mal size in from 5 days to 2 weeks, usually in less than 10 days. Consequently, a quarantine period of 14 days is sufficient to guard against transmission by a simple uncomplicated case of mumps.

Susceptibility and immunity. While mumps is not as infectious as some of the other respiratory diseases, such as influenza or measles, nevertheless man is, in general, universally susceptible to the disease. As a rule, susceptibility is not influenced by either age, sex, race or geographical location *per se.* Usually one attack of mumps will produce permanent immunity, but second and sometimes third attacks occasionally occur.

Prevalence and importance. Mumps, like measles, occurs most frequently during childhood and the greater proportion of adults are immune to the disease. However, more of the men who enter the military service are susceptible to mumps than to measles. During the World War, there were 230,356 cases of mumps as compared with 96,817 cases of measles, among 4,000,000 American troops.

While mumps is a nonfatal disease, it is of great importance from a military viewpoint because of its high noneffective rate. During the World War, the noneffective rate for mumps was the third highest of all diseases, being exceeded only by the rates for influenza and gonorrhea.

Troops from rural districts have a much higher group susceptibility to mumps than those from urban communities. Mumps tends to be more prevalent during the winter months than in the summer.

Mumps is prone to occur in epidemic form wherever a considerable number of recruits are brought together, especially if they come from rural districts. Epidemics of mumps are not, as a rule, explosive in character, but rather the disease spreads slowly and an epidemic tends to be prolonged.

Control measures. The control of mumps is based mainly on the early detection and hospitalization of cases. Group quarantine of contacts may be employed but is not ordinarily effective in preventing the spread of the disease.

When a case of mumps occurs in an organization, the patient should be immediately hospitalized. If the case in question is a primary one, the contacts may be placed in group quar-

antine (page 23). Usually, however, secondary cases will eventually appear outside the quarantined group and render this method of control ineffective. As a rule, reliance must be placed on the physical examination of the entire organization for the detection of cases in the early stage of the disease.

Physical examination for prodromal symptoms. When mumps is present in an organization, any man complaining or showing evidence of illness should be sent at once to the hospital or dispensary for observation. If the disease threatens to become epidemic to an extent which would interfere with military activities, daily examinations of all troops for the early symptoms of mumps should be made by a medical officer. Usually the first definite symptom noticed is pain or tenderness in one or the other of the parotid glands marking the onset of the glandular involvement. This symptom may be elicited prior to evidence of glandular swelling by pressure over the glands or by opening the mouth wide. Hathcocks' sign, which consists of tenderness immediately beyond the angle of the jaw when the finger is pressed towards the angle under the mandible, is usually pathognomonic of mumps. There may also be redness and pouting of the orifices of Steno's ducts at this time.

Symptoms such as fever, malaise, headache, anorexia and pain in the back and legs, which are ordinarily present at the beginning of any infectious disease, may occur as prodromal symptoms of mumps during the invasional period. While not necessarily indicative of mumps, they should, when mumps is present in an organization, be regarded as suspicious and the individual should be hospitalized as a suspect.

Separation of susceptibles and immunes. Mumps susceptibles and immunes may be determined and separated by the same methods as described for measles (page 44).

Passive immunity. Passive immunity to mumps may be conferred by the injection of convalescent serum, but the employment of convalescent serum is not ordinarily a practical procedure for the control of the disease among troops. In general, the same methods are used as in the control of measles (page 45).

Complications. Orchitis is the most common complication of mumps among troops and is important because it prolongs the period of hospitalization and absence from duty. Orchitis may be an initial symptom. Among other complications

which may occur are acute pancreatitis and meningeal irritation or meningitis.

The incidence of complications, especially of orchitis, can be reduced by prompt hospitalization, by keeping the patient in bed, and by avoidance of cold. The slightest injury to the testes predisposes to the development of orchitis, and care should be taken to avoid traumatism, however slight, or even examination by palpation.

Disinfection. Concurrent disinfection should be practiced in the care of mumps in the hospital, particular attention being paid to articles contaminated with discharges from the mouth and nose (page 39).

It is not known how long the causal agent of mumps will live outside the body. The results obtained, however, indicate that terminal disinfection, consisting of general cleaning of floors and beds, with airing or sunning of the bedding, will suffice to prevent transmission of the infection.

MENINGOCOCCIC MENINGITIS
(*Cerebrospinal fever, Epidemic meningitis*)

Definition. Meningococcic meningitis is an acute infectious disease which is characterized clinically by sudden onset, headache, fever, mental clouding and other symptoms of meningeal inflammation. Atypical attacks occur and are manifested by a prolonged course, irregular temperature, a maculopapular or petechial rash appearing and disappearing at intervals, symptoms of arthritis, meningococcemia, and enlargement of the spleen. Meningitis may or may not develop late in the course of the infection.

Incubation period. The incubation period of meningococcic meningitis is variable and uncertain, but is generally considered as being from two to seven days. Occasionally, the incubation period may be as long as ten days. As the infection is, as a rule, derived from a carrier, it is usually difficult, if not impossible, to determine the time of exposure.

Etiology. Meningococcic meningitis is caused by the meningococcus (*Neisseria intracellularis, Diplococcus intracellularis meningitidis*). Several types, or groups, of meningococci have been demonstrated by serological methods. The more recent studies indicate that there are four immunological types of men-

ingococci, with perhaps a number of subtypes which cannot be definitely classified. The prevalence of the different types varies in different epidemics, and usually more than one type is present in any one epidemic. Type I and Type III are closely related and are more commonly found during epidemics than are the other types and subtypes.

Meningococci are present in the nasopharyngeal tissues, in the spinal fluid, and frequently, during the early stages of the disease, in the blood. In many instances, it has been found that the invasion of nasopharyngeal membranes by meningococci causes a mild inflammatory process (rhinopharyngitis).

Transmission. Meningococcic meningitis is essentially a carrier disease, in that the transmission of the infection from case to case is usually through the medium of a carrier or a series of carriers. It is seldom that a case of the disease is infected from another known case and, as a rule, there is no history of demonstrable contact between cases. The healthy carrier is the principal factor in the transmission of the infection and whenever meningitis occurs with epidemic prevalence, the healthy carriers always greatly outnumber the cases. It is highly probable that missed and mild cases also serve as sources of infection, particularly in the production of carrier epidemics.

The meningococci are disseminated in secretions discharged from the nose and mouth, the infected secretions being transferred by air (droplet infection), by the hands or by objects contaminated with fresh discharges.

Crowding, with the consequent close contact between individuals, is an essential factor in the transmission of the organisms with the consequent production of carriers and spread of the disease. Fatigue or other depressing influences, and exposure to inclement weather, serve to lessen group resistance to the infection and are important in the production of cases. Consequently, the development of epidemics is promoted by and to a certain extent dependent on *close contact, fatigue, depressing environmental conditions and exposure to cold and chilling weather.*

Meningococcic meningitis is communicable from the appearance of clinical symptoms until the patient ceases to be a convalescent carrier. It is probable that, at times, the disease is communicable during the incubation period, but it is seldom that

specific organisms can be demonstrated in the secretions during this time, or that a clinical diagnosis can be made during the brief prodromal stage.

Prevalence and importance. Meningococcic meningitis is more prevalent during childhood and early adult life, although it may occur at any age.

In the military service, meningococcic meningitis occurs most frequently as sporadic cases or as limited epidemics. The case fatality rate is comparatively high but the number of cases occurring at any one time is seldom sufficient to interfere seriously with military activities. During the World War, there were only 4,831 admissions to hospitals for meningococcic meningitis, but these cases caused 1,836 deaths—a case fatality rate of 38 per cent. The disease ranked seventy-fifth as a cause of admission to hospital.

From a strictly military viewpoint, meningococcic meningitis is important mainly because of its depressing effect on the morale of both the officer and enlisted personnel and not because of its influence on the noneffective rate. The occurrence of a few cases in a command arouses apprehension and fear on the part of the troops, while a large number of cases of a less fatal and more common disease, such as measles, cause but little concern.

Meningococcic meningitis tends to occur most frequently among untrained recruits. In war, its prevalence is greatest during the earlier part of the mobilization period. In peace, the occurrence of epidemics is facilitated by bringing together in one group large numbers of recruits fresh from civil life.

The incidence of meningococcic meningitis is highest during the winter and spring months. The greater crowding during cold weather and the increase in the incidence of other respiratory diseases facilitates the transmission of the infection with a consequent increase in the prevalence of carriers. Exposure to cold and inclement weather is no doubt an important factor in the development of cases and in prolonging the carrier state.

Where a sporadic case occurs in a military organization, it may be of no particular significance as far as epidemic conditions are concerned. The infection may have been derived from a carrier or case outside the organization and the contacts made by the patient within the organization do not produce a sufficient number of carriers to spread the infection among the

troops. On the other hand, the occurrence of a case may be the first indication of the existence of a carrier epidemic which, if uncontrolled, will result in an epidemic of cases.

Carriers. Many studies show that a population which is not exposed to contact with cases of meningococcic meningitis will have a meningococci carrier rate of from two to five per cent or even as great as ten per cent. However, the proportion of carriers found in a given survey will, within limits, depend on the skill with which the survey is made, including the care exercised in taking the specimen, the kind of medium used, and the methods employed in handling the specimen in transit.

In a population exposed to risk of infection by close or remote contact with cases of meningitis the carrier incidence may be as high as 80 per cent, especially if the organization is composed largely of recruits. Under like conditions, a carrier rate of from 20 to 50 per cent is not uncommon. There is a close relationship between an increase in the carrier rate and the appearance of cases of the disease, and also between the rise and fall in the carrier incidence and the increase and decrease in the number of cases. Apparently, the increase in the carrier rate causes an epidemic of cases and does not, as in certain other diseases, follow an epidemic of the disease.

By far the greater proportion of the carriers of meningococci are temporary, healthy carriers. Convalescent carriers occur but are few in number as compared with healthy carriers. Incubationary carriers are apparently quite rare and it is doubtful if a true carrier ever contracts the disease. Chronic healthy carriers are to be found and may serve as important sources of infection (*infra*). The chronic healthy carrier is frequently of the intermittent type.

Ordinarily, the carrier condition persists only for a relatively short time. It has been estimated that more than one-half of the carriers of meningococci become negative within four weeks after acquiring the organisms, but, nevertheless, in a considerable number the carrier state becomes essentially chronic and tends to persist for long periods of time. The fact that the carrier condition may be intermittent renders it difficult to determine when an individual carrier becomes permanently negative.

Susceptibility and immunity. Group susceptibility to meningococcic meningitis is low under ordinary conditions. The incidence of the disease is generally greatest among infants and among children less than ten years of age. Young adults are apparently much more susceptible than older people. Conditions which lower the resistance to infection, especially fatigue and chilling, augment group susceptibility to the disease.

There appears to be but little if any real difference in the susceptibility of troops coming from urban or rural districts. However, the greater prevalence of the common respiratory diseases among men from rural areas may facilitate the transmission of the infection and promote the development of carrier epidemics and cases.

Whether or not an attack of meningococcic meningitis confers immunity to subsequent infections has not been determined. Second attacks have been reported, but on the other hand serological studies have shown that immune substances are present in the sera of convalescents and patients who have recovered.

Control measures. Usually, an epidemic of meningitis is inaugurated by the occurrence of one case which is followed by other cases scattered as to time interval and location throughout the military organization or civilian community. It is seldom that any direct connection between cases can be demonstrated. The control of an existing epidemic of cases of meningitis must be, therefore, based primarily on the control of the pre-existing epidemic of carriers and the prevention of epidemics of the disease depends upon preventing the prior occurrence of carrier epidemics.

When a case of meningococcic meningitis occurs in a military organization, the patient should be thoroughly isolated in the hospital in order to prevent the production of carriers by contact. The occurrence of a single case of meningitis may or may not be the result of an existing carrier epidemic. Such a case may be sporadic or, on the contrary, it may herald the beginning of an epidemic of cases due to the spread of the infection by carriers. In sporadic cases, the infection may have been acquired by contact with a carrier or a case outside the command.

When a single case of meningitis appears in a military command, throat cultures from a representative sample of the organization should be taken and examined to determine if the incidence of carriers of meningococci is above normal. Generally, if the carrier incidence is above five per cent, control measures should be instituted. Where laboratory facilities for a carrier survey are not available, it must be assumed that the occurrence of a case of meningitis is an indication of an increase in the prevalence of carriers.

Generally, the quarantine of a group of known carriers has no appreciable effect on the incidence of carriers or on the development of other cases in the command as a whole. Where the patient contracted the infection from a source outside the command, and the organization as a group has not been exposed to other sources of infection, group quarantine of the close contacts may prevent an increase in the incidence of carriers throughout the organization. In most instances, however, the prevalence of carriers outside the quarantined group will render quarantine of contacts useless as a control measure.

If group quarantine of carriers or contacts is established it should be maintained for fourteen days, or, if secondary cases occur in the quarantined group, for fourteen days subsequent to the removal of the last case.

The carrier condition is intermittent in at least a fair proportion of the individuals concerned and the carrier state may persist for weeks or even months. The difficulty of determining by examination of throat cultures when any particular carrier has become negative is increased by the tendency for the carrier condition to be intermittent, and the ever present possibility that the throat swab was not properly taken, or that the organisms present in the throat were missed. Under these circumstances it is not feasible to utilize as a criterion for the release of carriers from quarantine or observation an arbitrarily established number of negative cultures during a given period of time. It is usually impracticable to quarantine or maintain close observation of chronic carriers for the long and indefinite period of time required for them to become permanently negative. Moreover, as an exposed population will contain a large number of carriers and as it is probable that carriers will be found in any unexposed group, the

quarantine of carriers is of doubtful value in the control of the disease.

Recent work indicates that the chronic, intermittent carrier of Type I-III meningococci is a most important source of infection and that such a carrier in a community may cause a number of sporadic cases which are apparently not epidemiologically related to one another. The identification and subsequent isolation of such a carrier may be an important factor in the control of a local epidemic or in preventing the sporadic occurrence of the disease.

In considering the control of carriers it is important to remember that meningococcus carriers do not, as a group, transmit meningitis nearly as readily or as frequently as typhoid carriers transmit typhoid fever. Some are carriers of Type I-III meningococci but many others are carriers of the less virulent types. It is probable that many of the carriers found by the ordinary survey are carriers of the less virulent types, and it is likewise possible that some of the virulent types, or that the virulent types in some epidemics, have less invasive ability. The failure of meningococcus carriers to produce cases as constantly as do the carriers of the causative agents of certain other diseases may be due not only to low invasive power of the organisms, but also to an inability to transmit the organisms in sufficient numbers, and to the low susceptibility of those exposed to risk of infection. In any event the meningococcus carrier is of far less importance, from an epidemiological viewpoint, than the carriers of such diseases as typhoid fever or dysentery. Consequently, measures as severe as those which are taken to control typhoid or dysentery carriers are not justified in the control of meningococcus carriers.

The prevention of crowding is the most effective control measure. The primary purpose of separating individuals one from the other is to reduce the prevalence of carriers of meningococci. Close contact between individuals promotes the production of carriers and in turn the occurrence of cases. It has been observed that there is, within limits, a direct relationship between the increase in the prevalence of meningococcus carriers and the degree of crowding, especially crowding in squad rooms and tents. However, in order to affect favorably the incidence of carriers, the measures taken to prevent crowding

must be applicable at all times. The prevention of undue crowding in squad rooms is not sufficient if crowding is permitted in day rooms, in the mess halls, theaters and elsewhere (page 32).

In the presence of meningococcic meningitis, or when it is known or suspected that an organization contains an excessive number of carriers, the floor space allowed for each bed in squad rooms or tents should be increased to the maximum available. In any event, the beds should be separated by at least five feet of clear space (page 140). Where sufficient space is not available, cubicles should be used to prevent the transmission of infected secretions by air (page 33). Crowding outside of sleeping quarters, in theaters, day rooms, mess halls, or at places of duty, should be reduced to a minimum even though such action does inconvenience those concerned (page 32). It must not be forgotten that the crowding together of troops at military formations, such as close order drill or parades, may be an important factor in the transmission of infection from one person to another. Consequently, crowding of this nature must also be reduced to the practicable minimum if a carrier epidemic is to be controlled effectively.

Where meningococcus infection is present among a body of troops, crowding on transports is particularly apt to result in the development of an epidemic of meningococcic meningitis. If there is reason to suspect that carriers are present, or a case occurs among troops aboard ship, every effort should be made to prevent crowding in the troop quarters. The troops should be kept on deck for as much of the time each day as the weather and their duties will permit.

Satisfactory results have not been obtained from the treatment of carriers with drugs. Various antiseptics, including tincture of iodine, different cresol preparations, dichloramine T, silver nitrate and others may be applied to the membranes of the nose and throat, but they are generally of little value. *Moderate exercise* and *exposure to sunshine* are, apparently, the most effective measures for shortening the duration of the carrier state. However, in most instances, the carrier state is self limiting and tends to disappear in from two weeks to two months.

Chronic inflammatory conditions of the nose and throat may favor the development and prolongation of a chronic carrier state. Appropriate treatment of the underlying conditions is indicated in the treatment of the chronic carrier state.

Fatigue and exposure. Many observers have noted that fatigue or exposure to cold or wet weather seems to increase the susceptibility of the individual to infection with meningococci. There is good epidemiological evidence that the prevalence of meningitis or the incidence of carriers is greater among exposed groups of persons, such as troops, who have been subjected to conditions producing fatigue or chilling. In the presence of meningitis, or when there is potential danger of an epidemic, the troops, especially recruits who are undergoing training, should be protected from fatigue and undue exposure. If the situation is serious it may be found desirable or necessary to suspend training and other fatiguing duties for a time until the carrier incidence is reduced.

Physical examination of contacts. Where practicable, close contacts of meningitis should be examined daily by a medical officer for early clinical manifestations of the disease with special attention to the detection of atypical cases. The prompt isolation of early or atypical cases of the disease will reduce the number of carriers produced and will afford a better opportunity for the treatment of the patient.

The onset is usually sudden and the prodromal symptoms are inconstant and variable. Headache, fever and vomiting are common early symptoms and any person who exhibits any symptom indicative of meningitis should be hospitalized for observation.

If meningitis becomes epidemic, it may be desirable to make daily physical examination of entire organizations. In any event, company officers or noncommissioned officers should send any man who complains or shows signs of illness to the hospital at once.

Specific measures. Recent studies by Ferry and other workers have shown that a skin test may possibly be of value in determining susceptibility or immunity to meningococcic meningitis. The test is made by injecting intradermally a meningococcus toxin. A positive reaction, consisting of a reddened area at least ten millimeters in diameter, is regarded as indicating susceptibility to the disease. It has been further demonstrated by Ferry that certain susceptible persons can be rendered immune to the skin test dose of meningococcus toxin by three subcutaneous injections of the toxin in graduated doses. Immunity against the toxin of one type of the organism can be

produced by the injection of a mixed toxin of all types. Whether or not protection against the disease can be conferred by this method can be determined only by further studies.

Disinfection. The meningococcus is a very delicate organism and will survive only for a short time outside the body under ordinary conditions. Nevertheless, thorough concurrent disinfection should be practiced in the care of patients in order to minimize the production of carriers among the hospital personnel. Special attention should be given to the destruction or disinfection of all articles soiled with secretions from the nose and mouth. Terminal disinfection need consist only of thorough cleaning, with sunning or airing of blankets and mattresses.

DIPHTHERIA

Definition. Diphtheria is an acute infectious disease which is caused by *Corynebacterium diphtheriae* (*Bacillus diphtheriae,* Klebs-Loffler bacillus). It is manifested clinically by symptoms of toxemia and the formation of a characteristic membrane in the pharynx, larynx or nasal passages, on other mucous membranes, or on the surface of wounds.

Incubation period. The incubation period of diphtheria varies from one to five days. In the event of massive infection, the incubation period may be less than 24 hours. Occasionally, it may be longer than five days, but rarely more than seven days.

Transmission. Diphtheria is transmitted by persons having the disease and by carriers. It is probable that missed cases are important sources of infection.

The diphtheria bacilli are contained in discharges from the mouth and nose and are transferred directly from person to person by droplet infection, and indirectly by the hands and by articles contaminated with infected discharges. Food, especially milk and milk products, may serve as an agency for the transmission of the diphtheria bacilli.

Diphtheria bacilli are readily destroyed by sunlight, drying, and weak disinfectants. They may, however, remain alive and virulent for comparatively long periods of time in dried discharges or desiccated diphtheritic membrane, especially if protected from light. Consequently, diphtheria is more

readily transmitted by fomites than are such diseases as measles or mumps.

The period of communicability begins with the onset of the disease, and possibly during the incubation period, and continues into the convalescent stage until the secretions no longer contain virulent diphtheria bacilli. The bacilli persist in the secretions from the nose and throat for a variable time after the termination of the active stage of the disease. More rarely, the carrier state may persist for more than a month, and occasionally for two months or longer, after all clinical evidence of the disease has disappeared.

Susceptibility and immunity. Diphtheria is essentially a childhood disease. Maximum susceptibility occurs between the ages of one and ten years, although persons of any age may be susceptible. Infants whose mothers were immune are relatively immune until about the sixth month of life. This passive congenital immunity usually disappears completely by about the ninth month. At least 70 to 75 per cent of two year old children are susceptible to diphtheria. Thereafter, the proportion gradually diminishes until at 20 years of age less than 20 per cent are susceptible to the disease.

The immunity conferred by an attack of the disease is of variable duration. It is generally temporary in nature, lasting from several weeks to several years, although an attack may, in some instances, produce permanent immunity. However, the great majority of those who become immune to diphtheria do so without presenting clinical symptoms of the disease.

The immunity to diphtheria is an antitoxic immunity. Naturally acquired immunity to diphtheria toxin is believed to result from repeated exposures to infection, none of which produces a clinically demonstrable attack of diphtheria. Under these circumstances, both the absence of symptoms and the development of a permanent immunity may, theoretically, be attributed to the power of the individual to produce antitoxin rapidly and in sufficient quantity to prevent the development of toxemia. Conversely, the development of toxemia or the failure of an attack to produce permanent immunity may be due to the inability or failure of the individual to produce sufficient antitoxin.

Immunity is acquired earlier in life by people living in crowded urban districts, especially those who live in the more crowded poorer districts of the larger cities, than by the inhabitants of rural areas, or small or isolated communities. Consequently, group susceptibility to diphtheria is higher among those drawn from rural districts than among those recruited from the cities.

Carriers. The diphtheria bacilli disseminated by healthy carriers may be virulent or nonvirulent. In civilian communities, in times of ordinary diphtheria prevalence, one to two per cent of the population are carriers of diphtheria-like organisms, but only about ten per cent of these carriers are carriers of virulent diphtheria bacilli.

Healthy carriers of virulent organisms are, as a rule, produced only by close contact with a diphtheria patient or with a person who has been in close contact with a diphtheria patient. Convalescent carriers are practically always carriers of virulent bacilli.

While the major portion of diphtheria incidence is due to carrier transmission, extensive carrier epidemics do not occur and diphtheria is not a carrier disease to the same degree as meningococcic meningitis (page 68). One case of diphtheria is relatively closely connected with another case, in that the infection is acquired either by actual contact or through the medium of a close contact carrier. Remote contacts (page 17) are not usually an important factor in the transmission of diphtheria.

The Schick test. Resistance to diphtheria depends on the presence of antitoxin in the blood and tissues. The Schick test determines if the blood and tissues contain sufficient antitoxin to counteract the toxin produced by the diphtheria organisms acquired by exposure under ordinary conditions. A negative reaction is regarded as indicating that the blood of the tested individual contains at least one-thirtieth of a unit of antitoxin per cubic centimeter. A negative reaction does not, however, necessarily prove that the individual is immune to massive infection.

The Shick test consists of the injection *into the skin* of the arm or forearm of a quantity of toxin which corresponds exactly to 1/50th of the minimum lethal dose (M. L. D.) for a 250 gram guinea pig. The toxin should be diluted to exactly 0.2 c.c. with

normal saline, but an injection which is not less than 0.1 c.c., nor more than 0.3 c.c. in volume, will give satisfactory results. A control test should be made by injecting heated toxin into the skin of the opposite arm. The toxin employed in the control test is heated to 75°C. for five minutes.

The reaction to the Schick test may be positive, negative, pseudo, or combined pseudo and positive. A positive reaction, which is indicative of susceptibility to diphtheria, consists, when fully developed, of a circumscribed area of redness from one to two centimeters (or approximately from 0.5 to 1 inch) in diameter. A trace of redness appears at the site of the injection in from 12 to 24 hours and, as a rule, becomes fully developed on the third or fourth day after injection. The reaction persists for from one to two weeks and disappears by gradually fading, with slight superficial scaling and brownish pigmentation of the skin.

When the reaction is negative, no inflammatory reaction is produced by the toxin or, at the most, there is only a transient redness.

A pseudoreaction may be produced by the protein in the toxin. The usual pseudoreaction is urticarial in nature and appears within from 12 to 18 hours after the injection. It becomes fully developed within 36 to 48 hours, and disappears within 3 to 4 days. There is usually no pigmentation. If a control injection has been made, it will, in most instances, also develop a pseudoreaction. Pseudoreactions are much more common in adults than in children. At times, although rarely, a pseudoreaction persists and is difficult to differentiate from a positive reaction. In such cases, the reaction should be regarded as positive until a retest reveals its true nature.

A combined positive and pseudoreaction may occur. Usually, a combined reaction can be differentiated from a pseudoreaction by the fact that it persists after the pseudoreaction at the site of the control injection has disappeared, and is followed by pigmentation and scaling of the skin. All doubtful combined reactions should be regarded as positive unless further tests show that they are definitely negative.

A small percentage of persons, mostly adults, who present a positive reaction to the Shick test are actually immune to diphtheria infection. This is assumed to be due to a cellular or tissue immunity.

Prevalence and importance. Among troops, the occurrence of diphtheria is usually sporadic rather than epidemic, although limited epidemics may occur where conditions are favorable for the spread of the infection.

The low group susceptibility to diphtheria, the fact that remote contacts are not usually carriers of the virulent organisms, and the relatively low infectivity of the causal organisms, reduce the probabilities that a given susceptible individual will, under normal conditions, make sufficiently close contact with a case or carrier of virulent organisms to become infected. Consequently, diphtheria tends to occur with epidemic prevalence only in the presence of overcrowding, and more especially long continued overcrowding. Under these conditions, the number of close contacts is increased, with the consequent increase in the number of carriers of the virulent organisms. Further, the opportunities for massive infection are likewise increased. Crowding aboard transports and trains is particularly prone to result in epidemic prevalence.

Normally, the incidence of diphtheria is highest during the fall and winter seasons of the year, generally during the late autumn months. However, in the presence of overcrowding and other conditions favoring the spread of the infection, epidemics of diphtheria may occur during any part of the year.

Geographically, diphtheria occurs throughout the world but the prevalence of the disease is somewhat lower in tropical and subtropical regions than in the colder regions.

Among American troops, the incidence of diphtheria is seldom sufficient to interfere seriously with military operations. This is due largely to the fact that adequate control measures are available and to the generally high group immunity. During the World War, there were 10,907 admissions among approximately 4,000,0000 troops, with an annual admission rate of 2.67 per 1000 strength. There were only three instances in which the disease became definitely epidemic in prevalence.

General control measures. Control measures are available by which diphtheria can be eradicated from any community, military or civilian. Susceptibility can be determined by the Schick test and active immunity can be conferred by immunization with toxin-antitoxin or toxoid. However, in a military organization the adverse effect which the expected

prevalence of diphtheria would have on the activities of the organization is not sufficient, except in selected situations, to justify the loss of time and the expenditure of effort which would be required to Shick test the entire command and to immunize all positive reactors. Ordinarily, control measures which provide for placing close contacts in group quarantine, and the early detection of cases and treatment with antitoxin in therapeutic doses will suffice to prevent the occurrence of epidemics.

Contact and carrier control. Under average conditions in garrison, or in stable situations in the field, when a case of diphtheria occurs in an organization, the patient should be hospitalized and the close contacts placed in group quarantine. If laboratory facilities are available, the contacts should be cultured to determine if they are carriers of virulent diphtheria bacilli. All contacts should be Schick tested. Those who present a negative Schick reaction and who are not carriers of virulent organisms, may be immediately released from quarantine. Those having a positive Schick reaction, but who are not carriers of virulent organisms, should be retained in group quarantine for one week after the removal of the last case, or if contacts are cultured, after the removal of the carriers of virulent organisms.

All carriers of virulent diphtheria bacilli, or if virulence tests are not made, all carriers of diphtheroid organisms, should be removed from contact with other members of the quarantined group who are Schick positive, but are not carriers, and isolated in a separate group. Even though virulence tests are to be made, all carriers of diphtheria bacillus-like organisms should, if practicable, be quarantined in a group by themselves until the virulence of the organisms can be ascertained.

If no laboratory facilities are available for culture work, or if for any other reason contacts are not cultured, all close contacts who have a positive Schick reaction should remain in group quarantine for a period of one week after the removal of the primary case, or the last case if secondary cases occur.

In the presence of an epidemic of diphtheria, remote contacts should be cultured if laboratory facilities and personnel are available for such work.

The members of a quarantined group should be physically examined daily by a medical officer for symptoms of diphtheria. The first prodromal symptoms may be quite mild and consist only of a slight rise in temperature or a mild sore throat. Cultures from the throat and nose may fail to reveal diphtheria bacilli at this stage of the disease. However, any Schick positive close contact of a case of diphtheria who shows a rise in temperature or a sore throat during the incubation period after contact, should be regarded as a case of diphtheria. He should be immediately hospitalized and given a full therapeutic dose of diphtheria antitoxin. Under these conditions, the administration of therapeutic antitoxin should not be delayed pending the receipt of a laboratory report on cultures.

There is no satisfactory method of treating diphtheria carriers. Tonsillectomy may effect a cure of the chronic carrier state where the foci of infection are in the tonsils. Disinfectants are of little value. The carrier state is usually temporary and tends to disappear in a short time without treatment. Carriers of virulent organisms, including convalescent carriers, should not be released from quarantine until two cultures from the throat and two from the nose, taken at intervals of not less than 24 hours, and preferably 48 hours, are negative for diphtheria bacilli.

Passive immunization. Passive immunity to diphtheria can be conferred by the injection of 500 to 1500 units of diphtheria antitoxin, the quantity depending on the age of the person to be immunized. In the immunization of adults, 1500 units should be used. The immunity produced by antitoxin alone is transitory and does not, ordinarily, last for more than from three to four weeks.

While diphtheria antitoxin in immunizing doses will afford complete protection for the individual for the time being, its use as a general control measure among troops is, under ordinary conditions, impracticable. It does not prevent the carrier state and, because of the relatively transient nature of the immunity produced, the immunized individual does not continue to be protected, either from the organisms which he may carry, or from those which he may acquire from later exposures. Immunization with antitoxin is not, therefore, a substitute for contact and carrier control, nor for active

immunization. However, in certain situations, antitoxin can be used to good advantage as an emergency control measure. For example, where it is necessary to employ Schick positive personnel, or personnel which cannot be Shick tested, in the care of diphtheria cases or carriers, antitoxin may be used to obtain temporary protection for such personnel. Also, under conditions which do not permit the daily examination of contacts for clinical symptoms, it may be found desirable to administer antitoxin in immunizing doses.

Active immunization. Active immunity against diphtheria can be produced by the injection of modified diphtheria toxin. Two such modified toxins are used for this purpose, the toxin-antitoxin mixture and toxoid (anatoxin). The toxin-antitoxin mixture consists of one-tenth L+ dose of toxin mixed with and partially neutralized by antitoxin. Toxoid is made by the addition of formalin to a toxin and holding it at a temperature of 37°C. for several weeks. While toxoid is atoxic, it possesses antigenic properties which will produce active immunity in the same manner as the toxin-antitoxin mixture.

Alum precipitated toxoid is prepared by the addition of alum to a toxoid solution, washing the precipitate with normal saline solution and redissolving the washed precipitate in normal saline by the addition of a small quantity of sodium citrate. The alum-precipitated toxoid contains about twenty per cent or even less of the original nitrogen content of the untreated toxoid while there is relatively slight decrease in specific antigen. Consequently, the reactions following the injection of the alum-precipitated toxoid are usually much less severe than those produced by the untreated toxoid.

As an immunizing agent, alum-precipitated toxoid or plain toxoid is superior to the toxin-antitoxin mixtures. The alum-precipitated toxoid is but slowly absorbed, as compared with the untreated toxoid or toxin-antitoxin, and a lump may remain perceptible at the site of injection for a number of days. The slow absorption probably accounts for the superior antigenic qualities of the alum-precipitated toxoid.

The antitoxic immunity produced by either toxin-antitoxin or toxoid develops slowly, requiring from two to three weeks to several months to reach a degree which will protect the individual from the disease. Consequently, active immunization can-

not be utilized to prevent the development of diphtheria by those who have been exposed to the infection. Further, if antitoxin is used to produce passive immunity in exposed individuals, the toxin-antitoxin or toxoid cannot be used at the same time to produce active immunity, as the excess quantity of antitoxin will counteract the antigenic properties of the toxin or toxoid. Active immunization should not be attempted until three weeks or more after the administration of antitoxin.

The active immunity produced by either antitoxin or toxoid is apparently permanent. One injection, or one course if more than one dose is given, of the alum-precipitated toxoid will immunize 95 per cent or more of the individuals so treated while one course of the toxin-antitoxin will immunize about 75 per cent. In any event, all those receiving either toxin-antitoxin or toxoid should, where practicable, be Schick tested after three months and given another course if the reaction is positive.

The toxin-antitoxin is given in three subcutaneous injections of one c.c. each at weekly intervals. The alum-precipitated toxoid is usually given in one subcutaneous injection of one c.c. The plain toxoid may, however, be administered in two injections, usually of one c.c. each, with an interval of from seven to fourteen days between injections.

Any diphtheria toxin contains proteins derived from the autolysis of the bacilli during incubation and also from the culture medium. Consequently, marked protein reactions may follow the injection of either the toxin-antitoxin or the toxoid. As the pseudoreaction to the Schick test is also caused by proteins in the toxin, the more severe reactions following the injection of an immunizing dose occur almost entirely among those who present pseudoreactions to the Schick test.

Toxoid has the disadvantage that its use as an immunizing agent in adults is accompanied by a greater number of protein reactions. In this respect, the toxin-antitoxin mixture is preferable to toxoid for the immunization of those who present pseudoreactions to the Schick test.

As compared with toxin-antoxin, the use of toxoid has the advantage that it will not sensitize to horse serum, as it contains no antitoxin and, therefore, no serum. However, the danger of sensitization by the injection of the toxin-antitoxin mixture is slight and is not alone sufficient to justify abandoning its use where it is otherwise indicated.

Toxoid reaction test. If toxoid is to be used, children over six years of age and adults should, where practicable, be given a reaction test. One such test consists of an intradermal injection of 0.1 c.c. of toxoid diluted one to twenty with physiological salt solution. If a reddened area at least one-half inch in diameter develops at the point of injection within 24 to 72 hours, the test is regarded as positive. A positive reaction indicates that the tested individual is sensitive to the protein in the toxoid. Positive reactors should be immunized with diluted toxoid, or, if practicable, with toxin-antitoxin.

Active immunization of children. All children living on a military reservation should be immunized with toxin-antitoxin or toxoid. Children between the ages of six months and six years may be assumed to be susceptible, and the alum-precipitated or plain toxoid should be given without a prior Schick test.. Children over six years of age should be Schick tested and the toxin-antitoxin or toxoid administered only to those having positive Schick reaction. Protein reactions are uncommon in children.

Protection of Medical Department personnel. All Medical Department personnel, including officers, nurses and enlisted men, whose duties may require them to come into close and prolonged contact with diphtheria cases or carriers, should be routinely Schick tested and the results recorded. Where practicable, all those having a Schick positive reaction should be immunized with toxin-antitoxin or toxoid.

Schick testing and active immunization of Medical Department personnel should be done before exposure occurs or threatens. Owing to the relatively long period of time required for the development of active immunity, adequate protection can be conferred after exposure only by passive immunization with antitoxin. Preferably, no Schick positive individuals should be placed on duty which would result in their exposure to diphtheria infection.

Disinfection. All articles which come into contact with the diphtheria patient and all articles soiled by discharges from the respiratory tract should be disinfected by steam, boiling, or chemical disinfectants, or destroyed by burning.

Terminal disinfection should consist of general cleaning of the room or ward and sunning.

SCARLET FEVER

Definition. Scarlet fever is an acute infectious disease manifested by sudden onset, sore throat, symptoms of general toxemia and a generalized, diffuse eruption followed by a characteristic desquamation.

The diagnosis of scarlet fever must, in practice, depend on the appearance of the characteristic rash followed by desquamation. It is quite probable that many cases of scarlet fever occur which do not present a rash but are, nevertheless, as infectious as the cases which do develop the rash.

Etiology. Scarlet fever is caused by a hemolytic streptococcus.

Incubation period. The incubation period may vary from one to seven days, but is usually from three to four days. An incubation period of eight days is regarded as the maximum for quarantine purposes.

Transmission. Scarlet fever is a typical contact disease, the causal agents being disseminated in the secretions from the nose and throat and, if a complicating otitis media is present, in the discharges from the ear. The infected material is spread from person to person by droplet infection, by contaminated articles and by hand to mouth transmission.

Food, especially milk and milk products, may also serve as a transmission agency in the spread of scarlet fever. A number of epidemics have occurred due to the infection of a milk supply by milk handlers having scarlet fever in a mild form.

Missed cases are apparently common sources of infection. It is probable that carriers also play an important role in the spread of scarlet fever. Direct transmission from case to case is rare, particularly among adults.

Scarlet fever is not nearly as infectious as measles, influenza or whooping cough. Roughly, not more than about fifty per cent of susceptible children will contract scarlet fever as the result of exposure to the infection, while in the transmission of measles a nonimmune person will almost invariably acquire the disease if exposed.

Scarlet fever is communicable from the onset of clinical symptoms until after all abnormal discharges from the nose, throat, ears or open lesions, have ceased. It is probable that

many scarlet fever patients cease to be infectious within three weeks after the onset. The period of communicability should be considered as being twenty-one days from the onset of the disease, provided an examination of the patient at the end of the twenty-one day period shows that there are no abnormal discharges from the nose, throat or ears. The patient should, however, be regarded as infectious without regard to lapse of time as long as the inflammatory conditions of the nose and throat persist or there is evidence of an active, complicating otitis media. Desquamation is in no way concerned in the transmission of the disease. The desquamated skin *per se* is not infectious.

Epidemiological evidence indicates that undoubtedly there are convalescent carriers of scarlet fever. It is probable that chronic carriers also exist. It is, however, believed by most workers in this field that scarlet fever is spread mainly by mild cases that pass undiagnosed. There are no procedures available at the present time by which carriers of the causal agents of scarlet fever can be definitely identified, except in so far as carriers of hemolytic streptococci may be considered to be carriers of scarlet fever.

Susceptibility and immunity. Scarlet fever, like diphtheria, is a disease of childhood. Maximum susceptibility occurs at about the sixth year of life and thereafter rapidly diminishes. Epidemiological evidence, together with the results of the Dick test, indicate that at the age of 20 years 80 to 90 per cent of the general population are immune to scarlet fever.

Adult negroes are apparently much less susceptible to scarlet fever than are members of the white race. During the World War, the annual admission rate was 3.05 per 1000 for white troops, as compared with 0.34 per 1000 for colored troops. In general, troops recruited from rural communities have a higher susceptibility to scarlet fever than those drawn from urban districts.

An attack of scarlet fever usually confers permanent immunity. While second attacks occur, they are comparatively rare. The great majority of immune persons give no history of having had the disease, but it is probable that these individuals have either had the disease in an undiagnosed form, or have acquired an immunity by contact with the infection

without developing the disease in a clinically demonstrable form.

The Dick test. The Dick test is based on the assumption that immunity to clinical scarlet fever depends on the presence in the blood and tissues of an antitoxin which will neutralize the toxin produced by the etiological streptococcus. The presence or absence of this antitoxin can be determined by the reaction following an intradermal injection of a minute quantity of the toxin. The studies which have been conducted over a period of years and under varying conditions have demonstrated that the Dick test is a reliable index of immunity or susceptibility to scarlet fever.

The Dick test is performed by injecting into the skin, usually of the arm or forearm, one skin test dose of the scarlet fever toxin. A skin test dose of the toxin is that amount of the toxin which will produce, in the majority of individuals susceptible to scarlet fever, a reaction consisting of an area of erythema at least one centimeter in diameter 24 hours after injection. This amount of toxin is diluted to exactly 0.1 c.c. in volume and all of the resulting solution is injected into the skin.

A positive Dick reaction consists of an oval, sometimes slightly elevated, area of redness one centimeter or more in diameter. The redness appears in from 6 to 12 hours after injection, and becomes fully developed in about 24 hours. Thereafter it subsides in from 24 to 48 hours without pigmentation or scaling. A negative reaction shows no erythema at the site of injection or the area of redness is less than one centimeter in diameter. A positive reaction is indicative of susceptibility and a negative reaction of immunity to scarlet fever.

Pseudoreactions occur frequently in adults but are rare in children. Pseudoreactions are difficult to differentiate from true positive reactions and, for this reason, control tests are seldom used. If control injections are made, the test material should consist of toxin neutralized by the addition of antitoxin, as the toxin is resistant to heat. All doubtful reactions should be regarded as positive.

Prevalence and importance. The normal prevalence of scarlet fever among troops tends to be sporadic, rather than epidemic, in nature. This is due to the low infectivity of the

causal agents and to high group immunity to the disease. However, small epidemics may and do occur, especially among recruits and in the presence of overcrowding.

Scarlet fever is not an important disease from a military viewpoint in that it seldom becomes sufficiently prevalent to interfere with military operations. During the World War, there were 11,673 cases admitted to hospitals, or an annual admission rate of 2.85 per 1000 strength.

Scarlet fever is more prevalent during the colder portion of the year, particularly during the late winter and early spring months.

The incidence of scarlet fever is low in tropical and subtropical regions and, apparently, the disease is less prevalent in the southern states than in the northern states.

Control measures. The control of scarlet fever among troops is based principally on the control of close contacts. When a case occurs in an organization, the patient should be removed to the hospital and all close contacts placed in group quarantine (page 23) for a period of eight days after the removal of the primary case, or after the removal of the last case, if secondary cases occur.

Ordinarily, it is not feasible nor practicable to culture the throats of contacts for the purpose of detecting carriers. If cultures are made, all those who are carriers of hemolytic streptococci should be regarded as carriers of scarlet fever. These carriers should be removed from the quarantined group and hospitalized for treatment of the carrier state.

Contacts may be Dick tested. If both Dick tests and cultures are made, those who present negative Dick tests and are not carriers of hemolytic streptococci may be released from quarantine. Those who are Dick positive and are not carriers should be retained in quarantine until the expiration of the quarantine period. Carriers should be hospitalized and treated (*supra*).

All persons in group quarantine or, if quarantine is not established, all those who are suspected of having been exposed, should be examined daily, or preferably twice daily, by a medical officer for the purpose of detecting prodromal symptoms of the disease. Typically, these symptoms consist of sore throat or fever. The period of invasion is short, usually not more than 24 to 48 hours, after which the eruption appears. Any person who has been, or who might have been, exposed to scarlet fever in-

fection and who develops fever or sore throat should be regarded as a suspect and hospitalized.

In the control of scarlet fever, as in the control of other respiratory diseases, general sanitary measures should be taken to prevent transmission of the infection. Particular attention should be devoted to the mess. In the presence of scarlet fever in a command all food handlers should be carefully and frequently examined to determine if any have the disease in an early stage or a mild form. Any food handler exhibiting symptoms of a respiratory infection, such as fever or an irritated throat, should be promptly removed from contact with the food of others. If troops are examined for the presence of carriers of hemolytic streptococci, all food handlers should be included in the survey.

The blanching test. The blanching test may be used as a diagnostic procedure in cases presenting a rash, but in which the diagnosis is doubtful. The test is performed by injecting intracutaneously from 0.1 to 0.2 c.c. of scarlet fever antitoxin. If the tested individual has scarlet fever, the rash at the point of injection will disappear in from four to thirty hours and be replaced by a blanched area an inch or more in diameter. The same reaction can be produced by the use of convalescent serum instead of antitoxin (*the Schultz-Charlton reaction*).

Passive immunization. Passive immunity to scarlet fever can be conferred by the injection of scarlet fever antitoxin. Usually, the dosage varies with the age from 50,000 neutralizing units (sufficient to neutralize 50,000 skin test doses of toxin) to 100,000 neutralizing units or more. The protection afforded by passive immunization is effective for only about two weeks.

The use of scarlet fever antitoxin for the purpose of obtaining passive immunity has the same disadvantages that attend the use of prophylactic diphtheria antitoxin (page 80). Its principal value is that of providing temporary protection for susceptible children who have been definitely exposed to scarlet fever. Convalescent serum can also be used to confer a temporary passive immunity.

Active immunization. An active immunity to clinical scarlet fever can be produced in susceptible persons by the injection of graduated doses of the scarlet fever toxin. The dosage has not as yet been standardized. From three to five injections are given at intervals of from one to two weeks.

The first dose should not exceed 500 skin test doses of the toxin. Thereafter, the size and number of doses vary according to the method used. The method advocated by the Scarlet Fever Committee consists of injections at weekly intervals of 500, 2,000, 8,000, 25,000 and 80,000 skin test doses, respectively. Final doses of as much as 100,000 skin test doses may be found desirable, or a sixth dose of from 80,000 to 100,000 skin test doses may be given. It is probable that immunity somewhat more temporary in duration, but still sufficiently solid to afford the desired protection, can be conferred by smaller doses. The dosage employed for this purpose varies. In one method, Dick positive individuals are given injections of 500, 2,000, 6,000 and 12,000 skin test doses at weekly intervals. Another method consists of injections of 500, 2,000, 10,000 and 20,000 skin test doses. Dick tests should be made two weeks subsequent to the last injection and those who are still Dick positive given additional injections.

Studies have indicated that approximately 90 per cent of those presenting a positive Dick test prior to immunization will be Dick negative after immunization. Following immunization, the Dick test remains negative in most instances for at least several years.

Systemic reactions may follow the injection of scarlet fever toxin. The reaction to scarlet fever toxin usually consists of malaise and nausea which persist for from a few hours to two days. In some instances, a scarlatiniform rash is present.

Several workers have endeavored to produce a toxoid which would immunize to scarlet fever. Veldee's toxoid is made by treating scarlet fever toxin with 0.4 per cent formalin followed by storage for a considerable period of time at 37°C. The toxoid is given by subcutaneous injection of three doses of 0.1 c.c., 0.4 c.c., and 0.8 c.c., at intervals of three weeks. The reactions are much less severe than when the toxin is used, and about 85 per cent of those receiving the toxoid are rendered Dick negative. Immunization to scarlet fever by means of a toxoid is, however, still in the experimental stage.

Active immunization against scarlet fever is not, ordinarily, practicable nor necessary in the control of scarlet fever among troops. It has not been proven to be as reliable as active immunization against diphtheria. The time required

to confer sufficient immunity to protect the individual, the high group resistance of troops to scarlet fever, and the low infectivity of the causal agents all serve to lessen the value of active immunization as a method of control.

Complications and sequelae. Scarlet fever is frequently associated with other diseases that may be prevalent, such as diphtheria, measles, mumps, or pneumonia. The most common complications are otitis media, cardiac involvement or nephritis. During the World War, 33 per cent of the admissions to hospital for scarlet fever were associated with other diseases or developed complications. Otitis media occurred most frequently as a complication, being reported in 3.1 per cent of the cases of scarlet fever.

Complications can be best prevented, or their severity decreased, by prompt hospitalization and treatment with therapeutic doses of scarlet fever antitoxin or convalescent serum. It is particularly important that cross infections be prevented in the care of scarlet fever cases in hospitals.

Protection of children of military garrisons. All children over six months of age should be Dick tested to determine their susceptibility to scarlet fever. Those found to be susceptible may be given scarlet fever toxin for the purpose of conferring an active immunity, but this method is not as reliable as active immunization against diphtheria nor has it been shown that the immunity conferred by the use of scarlet fever toxin is permanent. However, when there is danger of exposure to scarlet fever, children should be given the benefit of any degree of protection which can be afforded by active immunization.

Protection of Medical Department personnel. All Medical Department personnel whose duties may bring them into contact with scarlet fever cases should be Dick tested and the results recorded. Preferably, enlisted men who are Dick positive should not be detailed to duties which would result in their exposure to scarlet fever. Where exposure is deemed probable, all susceptibles should be given scarlet fever toxin for the purpose of producing active immunity to the disease.

Disinfection. Concurrent and terminal disinfection should be carried out in the same manner as in the control of diphtheria (page 83).

GERMAN MEASLES
(*Rubella*)

Definition. German measles is an acute infectious disease, manifested clinically by a rash which develops and fades rapidly, and a characteristic adenitis of the mastoid, occipital and cervical glands. The rash may be similar to and be confused with that of measles or scarlet fever.

The invasional stage is short, usually not more than 24 to 48 hours, and prodromal symptoms may or may not be present. If present, they consist of headache and slight rise in temperature with enlargement of the cervical glands. Ordinarily, the rash completely disappears within 72 hours.

Incubation period. The incubation period of German measles is usually about 15 to 18 days, but may vary from 12 days or less to 21 days.

Etiology. The causative agent of German measles is unknown, but it is believed by most authorities to be a filterable virus. Epidemiological studies indicate that the virus is contained in the discharges from the mouth, nose and throat.

Transmission. German measles is transmitted from person to person by contact, by droplet infection, on the hands, or by means of inanimate objects soiled with the infected discharges.

The existence of carriers of German measles has not been proven and it is probable that the infection is transmitted from case to case without the intervention of carriers. Missed cases are undoubtedly important sources of infection.

German measles is considered to be communicable from the beginning of the invasional period until eight days after the appearance of the rash.

Susceptibility and immunity. German measles is not as infectious as measles. Probably about 50 per cent of susceptible persons will contract the disease from one exposure. German measles is essentially a disease of childhood. One attack confers permanent immunity. There is no method by which immunity can be artificially produced.

Prevalence and importance. German measles tends to occur in epidemic form, although sporadic cases are not uncommon. The group immunity of American troops to German measles is comparatively high and, for this reason, the

prevalence of the disease is seldom sufficient to affect military activities. German measles is most prevalent during the colder months of the year.

German measles is practically a nonfatal disease among adults and serious complications rarely occur. It is important from a military viewpoint only because of any influence it might have on the noneffective rate.

Control measures. Primary cases of German measles must be differentiated from measles and scarlet fever, and unless such differential diagnosis can be made with certainty a doubtful case should, for purposes of control, be regarded as either measles or scarlet fever.

Cases of German measles should be removed from their organizations and quarantined in hospital. Otherwise, the measures employed to control the spread of common respiratory diseases should be enforced (page 54). Group quarantine is, as a rule, ineffective in preventing the occurrence of secondary cases. The long incubation period, the high group immunity and the relative mildness of the disease render impractical any control measure, such as group quarantine, which would interfere with the activities of the troops.

The members of organizations or groups in which German measles has occurred should, if practicable, be examined daily by a medical officer for early symptoms of the disease. Any man presenting evidence of a rash, swelling of the cervical glands, or fever should be removed to hospital for observation.

The mildness of the disease and the transient nature of the symptoms render it probable that some cases will escape detection, at least during the earlier stages of the disease, and continue to spread the infection.

In the presence of German measles, company officers and noncommissioned officers should report to the surgeon of the command all men who show any evidence of illness.

Disinfection. In the care of patients in hospital, precautions should be taken to prevent the spread of the infection by the hands and clothing of the attendants and by articles soiled with discharges from the respiratory tract. Terminal disinfection should consist of general cleaning of the surroundings and airing of clothing and bedding.

SMALLPOX
(*Variola*)

Definition. Smallpox is an acute infectious disease which is manifested clinically by sudden onset, definite prodromal symptoms consisting of headache, pain in the back, fever, and a characteristic eruption.

Etiology. The etiological agent of smallpox is a filterable virus. It is present in secretions from the mouth, nose and throat, in material from the vesicles and pustules, and in the crusts. The virus may be present in the feces and urine.

Incubation period. The incubation period of smallpox is usually from 10 to 13 days from exposure to the onset of prodromal symptoms. It may, occasionally, be somewhat shorter than 10 days or as long as 16 days.

Stage of invasion. The onset is usually sudden and is characterized by severe headache and backache with a rapid rise in temperature. However, the prodromal symptoms vary greatly in severity. They may be slight and transient or the invasional period may be manifested by evidence of acute toxemia. A prodromal scarlatiniform or morbilliform rash occasionally occurs during the period of invasion but usually disappears in a few hours. The invasional period lasts for from two to four days and terminates with the appearance of the true smallpox eruption.

The eruption. The eruption of smallpox tends to appear first on those portions of the body which are exposed or subject to irritation, that is, on the forehead at or near the hairline, the backs of the hands, the anterior surfaces of the wrists, and then on the face. Later, any part of the body surface, including the palms of the hands, the soles of the feet and the membranes of the mouth and nose, may be involved.

The eruption appears first as macules which soon develop into distinct, firm papules. As a rule, the appearance of hard, shot-like papules is the first indication of the eruption. About the sixth day after the onset, the papules become multilocular, umbilicated vesicles. The vesicle reaches the pustular stage on about the eighth day of the disease.

The skin lesions of smallpox do not develop in multiple crops and the majority of the lesions on the surface of any

one part of the body are all in the same stage of development. This is an important factor in the differentiation of mild smallpox from chickenpox.

Types of smallpox. Smallpox occurs in the unvaccinated with varying degrees of severity. It is possible that there are different strains of the causal virus which possess varying degrees of virulency. However, severe and fatal cases of smallpox may occur in the midst of an epidemic of mild cases.

Alastrim is a disease which prevails in the West Indies, notably in Jamaica, and is probably an aberrant form of smallpox. It closely resembles ordinary smallpox but tends to have a mild clinical course. Vaccinia protects against alastrim.

Smallpox is usually mild and clinically atypical in vaccinated persons who contract the disease after the immunity conferred by vaccination has been partially lost. This type is sometimes known as varioloid. Smallpox modified by vaccination may be difficult to differentiate from chickenpox.

Transmission. Smallpox is transmitted by the person having the disease. As far as can be determined, carriers of smallpox do not exist and epidemiological studies do not indicate that the disease is transmitted by carriers.

The causal agent of smallpox is transmitted from person to person by contact. It is probable that the infective virus is, as a rule, transferred in the discharges from the nose and mouth, by droplet infection, by the hands, or by contaminated articles. The infection is also transmitted in the material from the skin lesions through the medium of the hands or contaminated articles.

Susceptibility and immunity. Man is universally susceptible to smallpox without regard to age, race or sex. The disease is usually more fatal among negroes than among members of the white race.

As a rule, one attack of smallpox confers permanent immunity to future attacks. Second attacks occasionally occur, but are rare.

Prevalence and importance. The prevalence of smallpox is governed by the extent to which the members of any given community are vaccinated. In an unvaccinated population, smallpox is a disease of childhood and tends to occur in epidemic form. In a partially vaccinated population, the unvaccinated individuals may, because of lack of exposure, escape

the disease, but any unvaccinated individual, either child or adult, who has not had smallpox will contract the disease whenever he is definitely exposed to the infection.

As all members of the army are vaccinated on entry into the service and routinely at three-year intervals thereafter, the disease does not occur among troops, except when unvaccinated recruits are exposed before entry into the service, or where, because of lapse of time, the protection afforded by vaccination is no longer absolute.

During the World War, there were 979 cases of smallpox reported for the entire army and of these 126 were admitted to hospital for some disease other than smallpox. Of the 853 cases which were primarily hospitalized because of smallpox, the records show that only 14 died. A large proportion of the cases occurred in individuals who were exposed to the infection prior to entering the army and developed the disease before complete protection could be conferred by vaccination.

Smallpox occurs in all parts of the world. It tends to be most prevalent during the colder months of the year.

Vaccination. Vaccination against smallpox consists of the introduction into the skin of the virus of vaccinia, or cowpox.

Vaccinia is generally considered to be smallpox which has been modified by the passage of the virus through animals. However, the characteristics of vaccinia are constant and transmission from one susceptible person to another produces vaccinia, not smallpox.

The vaccine virus. Vaccine virus, the causative agent of vaccinia, is obtained from the contents of the skin lesions of animals having vaccinia, or cowpox. The ordinary vaccine consists of lymph, or pulp, from lesions produced by the vaccination of calves. This material is purified and preserved in 50 per cent glycerine to which 0.5 per cent of phenol is usually added. The finished product is ordinarily placed in capillary tubes for shipment and use. The glycerinated virus is quickly destroyed by heat and deteriorates rapidly at room temperature. It will become inert in a few days if shipped in such a manner as to subject it to ordinary room temperature. Vaccine virus will, however, remain potent for at least three months if kept at a temperature of 41°F., or less. If stored

in an ordinary ice box, the container should be kept in direct contact with the ice.

Dried calf-lymph virus has been used to some extent and apparently will remain potent at ordinary temperatures for a much longer time than the glycerinated product. It has not come into common use, largely because of the difficulty experienced in obtaining an uncontaminated product.

Rivers and his colleagues, as well as other workers, have succeeded in cultivating the vaccinia virus in tissue culture. This work is still in an experimental stage, but the procedures being developed may render it feasible to grow large quantities of the virus in tissue culture and free from contamination. When frozen and dried, the virus produced by this method remains potent for a long period of time.

Methods of vaccination. Several methods are available by which the vaccine virus can be introduced into the skin. The most desirable method for use in vaccinating troops is one which will produce a small vaccinia lesion and thus reduce the noneffectiveness due to the reaction. The methods of choice are, therefore, the multiple pressure method and the single scratch or incision method.

Regardless of the method used, the preferable site for vaccination is the outer surface of the arm, usually the left arm, at about or slightly below the insertion of the deltoid muscle. The skin should be washed with soap and water and then sponged with acetone and allowed to dry. Ethyl alcohol or ether may be used instead of acetone.

The multiple pressure method. When the multiple pressure method of vaccination is used, the operator first grasps the arm on the under or inner surface in such a way as to pull the skin taut over the site of the vaccination. A small drop of the virus is then placed on the cleansed skin. A sharp, sterile needle is held horizontal to the surface of the arm, with the point resting on the skin within the drop of virus. The needle is pressed *firmly downward* until the epidermis slips over the point. The needle is then raised *directly upward* until the point is released. This operation is repeated not less than 25 times within an area about one-eighth of an inch in diameter. The point of the needle forces the virus into the cells of the skin where multiplication takes place. The excess virus is removed by wiping with a piece of sterile gauze. No dressing is required.

FIG. No. 4. Multiple pressure vaccination. Method of holding needle.

The multiple pressure method has the advantage that, when properly performed, no bleeding results and all evidence of trauma will disappear within six to eight hours. Therefore, no controls are necessary. A skilful operator can vaccinate with the multiple pressure method more rapidly than by any other procedure, due to the fact that less care is required to prevent bleeding. Speed is an important factor where large numbers of troops are to be vaccinated. The multiple pressure method will produce approximately the same number of reactions as the scratch method (Fig. No. 4).

The scratch method. With the scratch method, a scratch or incision about one-eighth of an inch in length is made in the epidermis with a sterile needle. Only one scratch should be made and it should not be deep enough to draw blood or, at the most, only a few small drops. The virus is rubbed into the incision with the side of the needle and the excess allowed to dry in place or is wiped away with sterile gauze.

A control scratch should be made without the virus at a point one to two inches away from the site of vaccination. The control scratch is desirable as an aid in differentiating an early immune reaction from a reaction due to trauma.

Ordinarily, no dressing is required but, if desired, a gauze dressing held in place with strips of adhesive may be used for 24 hours after vaccination. No occlusive dressing or shield should be used.

Other methods. The glycerinated vaccinia virus may be diluted with one part of sterile distilled water and injected intracutaneously. Experimentally, intracutaneous administration is the method of choice when the tissue culture virus is used (*supra*).

Reactions to the vaccine virus. Three types of reactions result from vaccination, the nature of which depends on the degree of immunity possessed by the vaccinated individual. *Vaccinia* occurs when the individual possesses no immunity; a *vac cinoid or accelerated reaction* is exhibited in the presence of partial immunity, and an *immune reaction* develops when the vaccinated person is immune to the virus. One of these reactions always results if the vaccination is properly performed. Should no reaction occur, the vaccine used was inert or the technique was faulty (Plate No. 1).

Vaccinia (*primary reaction or "take"*). Vaccinia, or a primary reaction, occurs when the vaccinated individual has never had smallpox and has never been vaccinated or when the immunity conferred by previous vaccination has disappeared.

The incubation period of vaccinia is from three to four days, sometimes as long as five days. During this time, there is no evidence of a reaction, except possibly a slight itching, or reddening of the skin due to trauma. About the third day, a papule appears at the site of vaccination which, on the fifth or sixth day after vaccination, becomes a vesicle. The vesicle is surrounded by a narrow, red, swollen area. This narrow, ring-like area expands to form the areola which reaches its maximum extent about the tenth day. The vesicle is umbilicated. It is at first clear or white in color, but as it grows larger it becomes yellowish and is converted into a pustule about the ninth day. At this stage, the skin is hot and tender and the axillary glands are usually swollen and painful. In a typical case, the maximum development is reached on about the tenth to the twelfth day, after which the swelling subsides, the pustule dries and a brown, wrinkled crust is formed. The crust usually comes away about the twenty-first day. It should never be forcibly removed.

REACTIONS TO SMALLPOX VACCINATION

These colored records represent a careful selection of the standard types of reactions which follow smallpox vaccination. They were painted from life by Leon Schlossberg, pupil of Max Brödel, in the Department of Art as Applied to Medicine, in the Johns Hopkins Medical School.

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Vaccinoid reaction (*accelerated or secondary reaction*). Where an individual is partially but not entirely immune to vaccinia, the reaction following vaccination tends to develop more rapidly, to be less severe, and to subside in a shorter period of time than a primary reaction. Such a reaction is called a vaccinoid or accelerated reaction.

The papule develops in about 36 hours after vaccination. The vesicle develops rapidly thereafter and is smaller than that produced by a primary reaction. The areola is also less extensive. The reaction reaches its maximum intensity between the fourth and eighth day, after which it rapidly subsides.

A vaccinoid reaction indicates that the individual was partially immune at the time of vaccination. It confers an immunity which has the same protecting power as a primary reaction.

The immune reaction (*immediate reaction; reaction of immunity*). The immune reaction consists of an area of redness, or a papule, which develops at the site of vaccination in from 12 to 24 hours after vaccination. The immune reaction reaches its maximum intensity in from 24 to 60 hours after vaccination and then gradually fades. No vesicle is produced and, ordinarily, there is no area of diffuse redness as in the primary or vaccinoid reactions.

Immune reactions indicate that, for the time being, the vaccinated individual is immune to both vaccinia and smallpox. It is not, however, a measure of the permanency of such immunity.

Nature and duration of immunity. The immunity conferred by vaccination with vaccine virus develops about the eighth day after vaccination and, consequently, vaccination shortly after exposure to smallpox will either prevent the development of the disease or lessen the severity of the attack.

The duration of the immunity created by vaccination varies in different persons. Usually, the immunity conferred by one vaccinia reaction is absolute for a few years and then gradually disappears and the individual again becomes susceptible. In the majority of instances, one who has been vaccinated but has again become susceptible to vaccinia, is likewise susceptible to smallpox but, occasionally, immunity to smallpox may be retained after the immunity to vaccinia is lost.

Studies based on the reactions following re-vaccination indicate that the immunity produced by one primary reaction

will, in general, protect against vaccinia, and therefore against smallpox, for from two to ten years. A few individuals may be protected for a much longer time, but usually re-vaccinations are necessary to preserve absolute immunity. Also, a few persons may lose their immunity before two years have elapsed after vaccination.

In the army, re-vaccination at three-year intervals has been found to be the most satisfactory method from both a disease control and an administrative viewpoint. With this method, a few sporadic cases of smallpox occur each year but all danger of an epidemic is obviated. Routine re-vaccination of all troops at less than three-year intervals would, no doubt, reduce the incidence of sporadic cases but, in the absence of exposure to smallpox, would not be justified on administrative grounds.

Complications. Complications following vaccination are extremely rare. Secondary infection of the wound produced by a primary reaction may occur, as it would in any open wound, but can be prevented by ordinary cleanliness and care. *Tetanus* has occurred following vaccination, but it is extremely doubtful if the organisms were introduced with the vaccine. It is probable that in most instances, if not in all, the infection was acquired secondarily by contact with dressings or shields contaminated with the spores of the tetanus bacillus, or with other sources of infection. No case of tetanus following vaccination has ever been reported as occurring among American troops.

Postvaccinal encephalomyelitis was first observed in London in 1922 and was reported later from Holland, Germany and other European countries. A few cases have occurred in the United States, but considering the number of vaccinations performed, the incidence is extremely low.

In postvaccinal encephalomyelitis the brain and spinal cord are involved, accompanied by demyelinization. The most prominent symptoms are headache, drowsiness, vomiting, rigidity of the neck, and Kernig's sign. The spinal fluid shows a high cell count and increased pressure. The symptoms usually occur between ten and thirteen days after vaccination, but may appear as early as five days or as late as thirty days subsequent to vaccination.

The principal theories advanced as to the cause of postvaccinal encephalomyelitis are that it is due to a neurotropic vaccine

virus, or that the symptoms are those of an allergic reaction to the vaccine virus.

Control measures. In a military organization, vaccination is the only measure of practical value in the control of smallpox. The high infectivity of the causal agent, the fact that the disease is transmissible during the stage of invasion, and probably also during the incubation period, and the high susceptibility of the unvaccinated individual, render quarantine ineffective in controlling the spread of the disease in an unvaccinated population.

When a case of smallpox occurs in a military organization, all members of the command whose official records do not show that they were vaccinated within the previous 12 months should be re-vaccinated. All those who were vaccinated between 6 and 12 months prior to occurrence of the case, but did not develop vaccinia, or an accelerated reaction, should be re-vaccinated. Those who were vaccinated less than six months before and who at that time presented definite immune reactions, are probably immune and need not be re-vaccinated. However, from an administrative viewpoint, under average conditions, where a sporadic case of smallpox occurs, the most satisfactory procedure is to re-vaccinate the entire command without regard to the results of previous vaccinations.

Usually, it requires less time and causes less confusion and less noneffectiveness to vaccinate an entire company, battalion or regiment, that it does to inspect the records and sort out and re-vaccinate only those men who actually require it. Vaccination will in no way incapacitate those who are immune, nor will it cause them any discomfort or inconvenience.

Disinfection. Although disinfection is a control measure of secondary importance in the prevention of smallpox, concurrent and terminal disinfection should be practiced as matters of administrative routine in the care of smallpox patients in hospital. The usual procedures should be employed (page 39).

CHICKENPOX
(*Varicella*)

Definition. Chickenpox is an acute infectious disease characterized by mild clinical symptoms and a papulovesicular eruption which occurs in successive crops.

Etiology. The causal agent of chickenpox is not known but probably belongs to the group of filterable viruses. It is present in the contents of the vesicles and possibly in the discharges from the upper respiratory tract.

Incubation period. The incubation period of chickenpox varies from two to three weeks, but is usually about 15 days. For purposes of control, three weeks is considered to be the maximum incubation period.

Susceptibility and immunity. Susceptibility to chickenpox is universal. One attack, as a rule, confers permanent immunity and second attacks are rare.

Importance and prevalence. Chickenpox *per se* is of but minor importance in the military service. The disease occurs most frequently in childhood so that the group susceptibility of troops is relatively low. Consequently, chickenpox tends to occur among troops as sporadic cases and small epidemics—not as extensive outbreaks. It is nonfatal.

Differentiation of chickenpox from smallpox. It is essential that chickenpox be differentiated from mild smallpox in order that re-vaccination will not be neglected in the presence of smallpox. The smallpox eruption usually appears first on the forehead, the backs of the hands, and the anterior surfaces of the wrists, and then spreads to other parts of the body, while the chickenpox eruption is, as a rule, first seen on the trunk, particularly on the back, after which it extends to the face and the rest of the body.

The smallpox vesicle is multilocular, while the chickenpox vesicle is unilocular. The latter usually collapses when pricked with a needle, and the former does not.

The smallpox eruption occurs as one crop and the eruption of chickenpox in a series of crops. The eruption of chickenpox is usually more marked on the scalp and back than the smallpox eruption. The skin lesion of chickenpox does not, as a rule, develop into a pustule.

The prodromal symptoms of chickenpox are generally mild, but may consist of fever, headache and pains in the back and extremities as severe as those which occur in mild cases of smallpox.

Transmission. Chickenpox is transmitted by contact, principally by transference of the contents of the lesions of the skin and mucous membranes. The vesicles in the membranes of the mouth appear before those of the skin and, as they usually rupture as soon as they appear, the disease may be communicated in the discharges from the mouth before the development of the vesicles on the skin. Presumably, the causal agent is also transmitted by articles soiled with the contents of the skin lesions. The disease continues to be communicable until the lesions are healed and all crusts have disappeared.

Control measures. Measures for the control of chickenpox among troops are mainly limited to the isolation of cases in hospital. The high group resistance of the troops and the mildness of the disease serve to render unprofitable any extensive control measures. Group quarantine is not usually effective, nor do the results obtained justify the employment of this measure. Close contacts should be examined daily by a medical officer during the incubation period in order that early cases and suspects may be detected and isolated.

If a sporadic case occurs which presents an eruption resembling that of chickenpox, but cannot be definitely and with certainty differentiated from mild smallpox, it should be regarded as smallpox and suitable control measures inaugurated.

SEPTIC SORE THROAT

(*Streptococcic sore throat, Epidemic sore throat*)

Definition. Septic sore throat is an acute infectious disease, characterized clinically by sudden onset, fever, intense inflammation and congestion of the tonsils and mucous membrane of the pharynx, which is accompanied in some cases by the formation of a pseudomembrane, prostration, and involvement of the cervical lymph glands.

Incubation period. The incubation period of septic sore throat is usually from one to three days, but may vary from less than 24 hours to four or five days.

Etiology. Septic sore throat is caused by hemolytic streptococci of human origin. It was formerly thought that the organism causing septic sore throat was a single variety or species of streptococcus, *Streptococcus epidemicus*. More recent work indicates that the disease is caused by more than one species of streptococci.

Susceptibility and immunity. Presumably, all persons are susceptible to infection with the strains of streptococci which cause epidemic sore throat, although epidemiological evidence indicates the existence of a certain degree of resistance to the infection. An attack of the disease apparently does not confer more than temporary immunity.

Transmission. The etiological agents of septic sore throat are contained in the discharges from the throat and the infection is transmitted either by contact or by infected milk. Usually, the organisms are transmitted in milk. Milk products, especially ice cream, may also serve as transmitting agents. In milk-borne epidemics, the primary source of infection is always a human case of the disease, or a human carrier of the streptococci, who as a milk handler either infects the milk supply directly or, in the act of milking, transmits the infection to the udder of the cow. The organisms thus planted in the udder multiply and are discharged in the milk. The udder may remain infected and serve as a source of infection for a considerable period of time, sometimes for as long as one or two months. Usually an udder infection with the causative streptococci is not accompanied by gross tissue changes, although the organisms and large numbers of pus cells are present in the milk. Occasionally, a mild, and more rarely an acute form of mastitis may be present. The bovine types of streptococci, which are ordinarily the cause of mastitis in cattle, do not cause septic sore throat.

While milk may be directly contaminated by the discharges from the throat of a person having the disease, or a carrier of the organisms, extensive epidemics of sore throat are usually caused by organisms derived from udder infections.

Septic sore throat tends to occur in epidemic form. As a rule, the epidemics are explosive in character, but may continue for a relatively long period of time if the infected animals are not eliminated as a source of milk supply, or the milk is not pasteurized. The characteristics of these epidemics are those of milk-borne infections, in that the great majority of the cases occur among the consumers of an infected raw milk supply. However, septic sore throat can be, and is, transmitted by contact in the same manner as any other respiratory disease. The infective agents contained in the discharges from the throat may be transferred from person to person by air, on the hands, or by means of contaminated articles. In practically every epidemic, secondary cases occur among those who are nonconsumers of milk or who did not consume any of the infected supply, but have been infected by contact with other cases. Also, sporadic cases or limited epidemics may occur in the absence of milk-borne infection and are due solely to contact transmission.

Control measures. The control of an epidemic of septic sore throat is based primarily on the pasteurization of the milk supply and the milk used in the manufacture of milk products (Chapter XI). The causal organisms are killed by a pasteurizing temperature and the disease is never transmitted by properly pasteurized milk.

Usually, if the milk supplied to the troops is obtained from two or more sources, the particular supply which is transmitting septic sore throat can be determined only by an epidemiological study.

Methods of control may include dairy inspection for the purpose of detecting infected animals (Chapter XI) and the examination of milk handlers to determine if any of them are carriers of the hemolytic streptococci. As a rule, however, satisfactory control can be obtained only by pasteurization of the milk or, in the absence of effective pasteurization, by rejecting the infected milk as a source of supply for troops.

In the presence of an epidemic of septic sore throat, the group quarantine of close contacts is usually of little control value because of the large number of cases. In selected situations, where there are only a few widely scattered cases, group quarantine of close contacts may yield good results in preventing the spread of the disease by contact. The group quarantine should

be conducted in the same manner as for any other respiratory disease (page 23) and need be maintained for only about one week after the removal of the primary case, or the last secondary case, if secondary cases occur.

Disinfection. Thorough concurrent disinfection should be practiced in the care of cases of septic sore throat in hospital in order to prevent the transmission of the disease to other patients or to the hospital personnel.

Terminal disinfection should consist of general cleaning, together with airing and sunning of the mattresses and blankets.

VINCENT'S ANGINA

(*Vincent's disease, Trench mouth, Ulceromembranous stomatitis*)

Definition. Vincent's angina is an acute, mildly infectious disease, characterized clinically by a slow onset, ulcerative stomatitis with the formation of a pseudomembrane, foul breath, and involvement of the adjacent lymph glands.

The ulceration and the pseudomembrane commonly involve the tonsils, but are also found on the gums, uvula and pharynx. In many instances, the lesions are unilateral. The larynx and bronchi may be affected by extension of the infection from the throat and mouth. The genitals may be involved with the production of balanitis. The salivary and cervical glands are usually swollen and painful. The glandular involvement may be unilateral or bilateral. Many cases are characterized by slight lesions and mild symptoms of a chronic nature. The incubation period is unknown.

Etiology. Vincent's angina is classified as a *fuso-spirochetal* disease caused by a fusiform bacillus (*Fusiformis dentium*) and a spirochete (*Treponema macrodentium, Treponema vincenti*). Whether the fusiform bacillus and the associated spirochete are different organisms or are different forms of the same organism has not been definitely determined.

Prevalence and importance. Vincent's angina tends to occur under unfavorable environmental conditions, such as, for example, during trench warfare. In normal situations, the infection is relatively uncommon, or at least it is infrequently diagnosed and reported. There were 6,189 primary

admissions for Vincent's angina from among all troops during the World War, with a consequent loss of 92,690 duty days.

Vincent's angina is also important because of the difficulty which is sometimes encountered in differentiating it from diphtheria or syphilis.

Transmission. The causal agents are contained in the discharges from the mouth. The disease is spread from person to person by contact, principally through the medium of contaminated articles and the hands. Poor oral hygiene and, to some extent, undernutrition and depressing psychic influences are predisposing factors. Mild, chronic cases are the most common sources of infection.

Vincent's angina is not highly infectious and the infection spreads but slowly, if at all, under good environmental conditions. One attack does not confer immunity to subsequent infections.

Control measures. Improvement in the general oral hygiene of the troops constitutes the principal method of controlling the spread of Vincent's angina. Cases should be isolated in hospital under conditions which prevent them from serving as sources of infection.

Where the disease is present in a command, special measures should be taken to prevent contact transmission by drinking cups, eating utensils, common towels, or similar articles, and by enforcement of the rules of personal hygiene, especially with regard to washing of the hands.

WHOOPING COUGH
(*Pertussis*)

Definition. Whooping cough is an acute infectious disease manifested by a catarrhal stage followed by a paroxysmal stage which is characterized by a spasmodic cough terminating in a "whooping" inspiration. The catarrhal stage of the disease is characterized by a tracheobronchitis and varies in duration from one to two weeks. Abortive and atypical attacks occur in which the characteristic paroxysmal stage does not develop.

Etiology. Whooping cough is caused by the bacillus of Bordet and Gengou (*Hemophilus pertussis*).

Incubation period. The incubation period is ordinarily from seven to ten days, but may be rarely as long as sixteen days.

Transmission. The etiological agents of whooping cough are present in the discharges from the upper respiratory tract and are transmitted from person to person by contact. Whooping cough is one of the most readily communicable of the infectious diseases. Apparently, only relatively slight and transient contact is required to transmit the infection by means of air-borne droplets or articles contaminated with infected secretions.

Healthy carriers are unknown. Epidemiological evidence indicates that mild and missed cases occur and that they are sources of infection.

Whooping cough is communicable from the onset of the catarrhal stage until at least three weeks after the development of the spasmodic cough. For control purposes the period of communicability begins seven days after exposure to the infection and continues until four weeks after the appearance of the paroxysmal stage of the disease.

Susceptibility and immunity. Susceptibility to whooping cough is universal and is not modified by race, sex, age or climate. In most instances one attack confers permanent immunity. Second attacks are rare, but they do occur. Secondary attacks may be mild and pass undiagnosed, but they serve as important sources of infection (*supra*).

Prevalence and importance. Whooping cough is essentially a disease of childhood. It is estimated that approximately 90 per cent of the cases occur in children under ten years of age. The incidence of reported cases among troops is low because of the high group resistance to infection. During the World War there were 119 primary admissions for whooping cough among approximately four million troops.

Whooping cough is a dangerous disease for young children, and has a relatively high mortality rate among those under two years of age. Death is usually caused by a complicating pneumonia.

Control measures. It is rarely necessary to institute measures for the control of whooping cough among troops. The high group resistance of adults to the infection renders it improbable that more than a very few secondary cases will

occur from exposure to a primary case. The patient should, however, be isolated for a period of four weeks after the first appearance of the spasmodic cough.

Early diagnosis and early isolation are important factors in controlling the spread of whooping cough among children. Cough plates may be used to detect the presence of the causal organisms during the catarrhal stage of the disease. Any child found to have *Hemophilus pertussis* in the secretions from the respiratory tract, or who, having been exposed to the disease, exhibits clinical symptoms of an upper respiratory infection, should be kept away from contact with nonimmune children. Complete isolation of a child who has whooping cough is difficult and usually impossible. In most instances, the child is not ill and suffers no discomfort except that caused by the spasmodic coughing. The isolation period is long, ordinarily from three to four weeks, and exercise and exposure to sunshine are valuable measures in the treatment of a mild attack of the disease. Under these conditions, it is impracticable to isolate completely a young child in a room or in the home. In practice, the child must be allowed to be out of doors and the cooperation of the parents obtained in preventing contact between the patient and nonimmune children.

Active immunization with vaccine made from a freshly isolated strain of *Hemophilus pertussis* of high antigenic power has been employed with varying success in preventing whooping cough. Recent studies indicate that properly prepared vaccines when given in large doses afford protection against the disease to a degree which will at least lessen the severity of the attack. The vaccine most commonly used contains ten billion organisms per c.c., and each child being immunized is given seven or eight c.c. by subcutaneous injection in graduated doses. One method is to inject 1 c.c. of the vaccine in each deltoid muscle, then one week later 1.5 c.c. in each biceps, followed after another week by the injection of 1.5 c.c. in each triceps. Some of the studies made indicate that the development of active immunity is relatively slow and that a high level is not reached for some weeks or possibly for three or more months after vaccination. In general, the results obtained by vaccination are, as yet, inconclusive.

Passive immunity can be conferred by the use of convalescent serum or whole adult blood. The immunity thus produced is of brief duration and this method of control is still of doubtful value.

POLIOMYELITIS

(Infantile paralysis, Acute anterior poliomyelitis)

Definition. Poliomyelitis is an acute infectious disease manifested by systemic symptoms of toxemia and a tendency for the infection to attack the gray matter of the spinal cord, especially that of the anterior horns, with the development of paralysis. The pre-paralytic stage may last for three or four days and is characterized by fever, irritability, drowsiness, nausea, stiffness of the neck and sometimes tenderness of the muscles of the extremities. The cellular content of the spinal fluid is increased during the early stages of the disease. The cell count is usually less than 100, but may be as high as 500 or more per cubic millimeter. Abortive cases may occur in which paralysis does not follow the pre-paralytic stage, but it is not likely that abortive cases would be diagnosed except in the presence of an epidemic.

Etiology. Poliomyelitis is caused by a specific filterable virus.

Incubation period. The incubation period is usually from seven to fourteen days, but may be as short as three or as long as eighteen days.

Transmission. The virus of poliomyelitis is present in discharges from the nose and throat, and possibly in the feces. It is transferred from person to person by air, by the hands and by contaminated articles. There is evidence that the infection may be transmitted by milk and other foods and possibly by water.

Epidemiological studies indicate that, as a rule, poliomyelitis is transmitted by carriers. It is probable that abortive or missed cases play an important role in the transmission of the disease. Occasionally, the infection can be traced from case to case, but usually there is no demonstrable connection between cases.

There is considerable evidence, but no definite proof, that the virus is carried to the central nervous system by the olfactory

nerves, and that the portal of entry is the olfactory area in the nose.

A number of studies have been made the results of which indicate that the infection may be intestinal in nature and that the virus enters the body through the intestinal tract.

The period of communicability of poliomyelitis has not been definitely determined, but probably begins during the incubation period and terminates within two weeks after the appearance of clinical symptoms.

Susceptibility and immunity. In most instances, one attack of the disease confers permanent immunity. Second attacks have been reported, but are rare. At least 90 per cent of the cases of poliomyelitis with paralysis occur before the twentieth year of life, and the great majority in children between one and ten years of age. The epidemiological characteristics of the disease indicate that many cases must occur without the development of the paralysis, but the individual case showing no paralysis is seldom diagnosed as poliomyelitis. Evidently, those having the disease in an abortive form develop immunity to the infection.

Prevalence. Poliomyelitis is not an important disease in military forces. Only 69 cases were reported as occurring among all troops during the World War. It is essential, however, that measures be taken to protect the children living at military stations from the disease.

Poliomyelitis tends to prevail in epidemic form during the late summer and autumn months, although epidemics may occur during the colder seasons of the year. Sporadic cases, or small limited epidemics are of common occurrence.

Poliomyelitis occurs in all parts of the world, but with much greater frequency in the temperate zone. Relatively few cases have been reported from tropical regions. During recent years there has been an apparent increase in the number of cases occurring in the Philippine Islands, especially among American children.

Poliomyelitis differs from many other infectious diseases in that it does not tend to spread within the family group. Usually, there is only one case in a family, although multiple cases do occur. It has been estimated that in only four or five

per cent of the families attacked will there be more than one case.

Control of poliomyelitis among children. *Quarantine.* Considering the present knowledge of the disease and the manner in which it is transmitted, the control of poliomyelitis among the children of a garrison must be based primarily on preventing contact between these children and sources of infection within or outside the station. When cases of the disease occur in the civilian population living adjacent to the station, the children of the garrison under sixteen years of age should not be permitted to leave the limits of the station. Nor should children residing in the civil communities where the disease has occurred be permitted to come into the station. This quarantine period should continue until at least three weeks after the occurrence of the last case.

When a case of poliomyelitis occurs among the children living on the station, the patient should be isolated for at least two weeks and all close contacts under sixteen years of age should be quarantined for three weeks.

Good judgment must be used and consideration given to all factors in determining whether or not in any given instance the children of a military post should be quarantined against neighboring civilian communities. Usually such a quarantine can be conducted without interfering seriously with the normal military activities of the garrison. A quarantine always has a good psychological effect in calming the fears of the parents, even though it may be unnecessary or useless as a control measure.

Chemical prophylaxis. Several groups of workers, including Schultz and Gebhardt, Armstrong and Harrison, and Sabin, Olitsky and Cox, have demonstrated that, in monkeys, spraying the olfactory mucosa with a solution containing an astringent chemical will prevent the entrance of the virus. This method has been tried in epidemics of poliomyelitis, but the low morbidity rate and the difficulties encountered in maintaining adequate controls have so far rendered it impossible to determine definitely if such treatment is actually effective in preventing the disease in humans.

Several different solutions have been used for intranasal spraying. The picric acid-alum spray consists of 0.5 per cent each of picric acid and sodium alum in 0.85 per cent saline solu-

tion. A spray containing 1 per cent of zinc sulphate and 0.5 per cent of pontocaine in physiological salt solution has been used with good results in protecting monkeys against intranasal instillations of the virus. Sprays consisting of a four per cent solution of alum, or a four per cent solution of tannic acid, have also yielded good results in work with monkeys. The picric acid-alum spray and the zinc sulphate sprays have been found to be the most satisfactory. No untoward results of a serious nature have been reported following the use of either the picric acid-alum spray or the zinc sulphate-pontocaine spray.

In order to be effective, the spray must be applied directly to the mucosa of the olfactory area. An atomizer should be used and the tip introduced upward and backward at an angle of about 45 degrees to a point past the middle turbinate. About one cubic centimeter of the solution should be instilled through each nostril. The spray should be applied by a medical officer, and not by a member of the family. The spray should be used every other day for a week and at weekly intervals thereafter, or every day for three successive days and then once a week.

In practice, the application of the spray presents many difficulties. The tip of the atomizer is apt to produce trauma, especially in young children. The sense of smell may be impaired for a considerable period of time, and any of the sprays may cause a severe and persistent headache.

At the present time chemical prophylaxis is still in the experimental stage and there is no definite proof that it will prevent infection with the virus of poliomyelitis. Nevertheless, in the presence of an epidemic of poliomyelitis, this method of protecting the children of a military garrison may be given consideration and employed where its use is indicated by the existing conditions. It should not, however, be relied upon to control the spread of the disease.

Immunization. No effective method of creating artificially an active immunity to poliomyelitis has, as yet, been developed. Several vaccines have been studied experimentally, but the results obtained do not justify their use. Formerly, it was thought that convalescent serum would confer a passive immunity to the disease, but further studies have demonstrated that it is of doubt-

ful value. If convalescent serum is used for this purpose it should be administered during the pre-paralytic stage.

Disinfection. Concurrent disinfection should be practiced in care of the isolated patient. All articles used by the patient and all discharges from the body should be thoroughly disinfected. No terminal disinfection, other than thorough cleaning, is necessary.

EPIDEMIC ENCEPHALITIS
(*Encephalitis lethargica*)

Definition. Epidemic encephalitis is an acute infectious disease of the central nervous system. The disease may develop suddenly or the onset may be gradual. Usually, the symptoms consist of fever of an irregular type, ophthalmoplegia and other evidence of nerve and brain involvement, with symptoms of motor irritation and psychic disturbances. Epidemic encephalitis varies greatly in symptomatology and severity. Some cases show marked somnolence or lethargy and because of this condition the disease has been improperly called "sleeping sickness". Recovery may be complete or, in non-fatal cases, the acute stage of the disease may be followed by a progressive involvement of the nervous system.

Epidemic encephalitis has been classified as two types—Type A and Type B.

Type A. In Type A, the onset is usually gradual and the course of the disease is chronic with considerable variability in symptomatology. There is a tendency for lethargy to develop, and Type A is frequently followed by sequelae characterized by mental deterioration.

Type B. In Type B, the disease is more acute than in Type A. The onset is more abrupt and there is less tendency for somnolence and ophthalmoplegia to occur. In non-fatal cases, recovery tends to be more prompt and complete.

Etiology. The results of a number of studies indicate that epidemic encephalitis is caused by a virus, and especially that the Type B form of the disease is due to a specific filterable virus. There is some evidence that the virus of encephalitis is related to the virus causing herpes, but the existence of such relationship has not as yet been proven.

Incubation period. The length of the incubation period has not been definitely determined, but it is probably not less than four days nor more than twenty-one days. Apparently, the incubation period of Type B is usually from nine to fourteen days.

Susceptibility and immunity. The distribution of epidemic encephalitis indicates that only a small part of the population is susceptible to the infection. Possibly, there are many mild cases which are not or cannot be diagnosed as encephalitis, although the occurrence of such mild or abortive cases has not been fully demonstrated. Presumably, one attack confers immunity, but this has not been proven.

Prevalence. There is considerable difference in the prevalence and distribution of Type A and Type B. Type A tends to occur as sporadic cases and Type B in sharp epidemics, as, for example, the epidemic in St. Louis, Missouri, in 1933, and the epidemics which have prevailed in Japan. Type A more commonly occurs during the latter part of the winter and the spring months, while Type B is more prevalent during the summer and autumn.

Transmission. It is thought that epidemic encephalitis is transmitted mainly, if not entirely, by means of air-borne infection and by articles contaminated with discharges from the nose and throat. It is probable that carriers play an important role in the spread of the disease, as it is seldom possible to trace the infection from one case to another.

Control. Only general measures are available for the control of epidemic encephalitis. The patient should be isolated for at least one week after the onset. If more than one case should occur in an organization, or where there are cases in nearby civilian communities, every effort should be made to detect early and suspected cases. Every person having suspicious symptoms should be isolated.

Because of the low group susceptibility to the disease, group quarantine would not be practicable as a control measure.

No effective method of conferring artificial active or passive immunity has been demonstrated.

In caring for the isolated patient, thorough concurrent disinfection should be carried out, especially with regard to

the disinfection of the discharges from the nose and throat (page 39). Terminal disinfection should be accomplished by methods outlined on page 40.

PSITTACOSIS
(*Parrot fever*)

Definition. Psittacosis is primarily a disease of parrots, parrakeets, canaries, and possibly other birds. In man, psittacosis is characterized by fever, a normal leucocyte count or leucopenia, anorexia, headache, backache, and sometimes insomnia and delirium. There is consolidation of the lungs, which usually begins near the hilum and spreads toward the periphery. The sputum is tenacious and usually scanty. Clinically, psittacosis resembles and may be confused with typhoid fever, influenza or atypical pneumonia.

Etiology. Psittacosis is caused by a specific filterable virus.

Incubation period. The incubation period of psittacosis in man is from six to fifteen days.

Susceptibility and immunity. Man is universally susceptible to psittacosis, although children are apparently more resistant than adults. No second attacks have been reported and it is generally believed that one attack confers permanent immunity.

Prevalence and importance. The distribution and prevalence of psittacosis depends upon contact between man and infected birds. Small epidemics of the disease have occurred in various parts of the world, and, in most instances, the infection was traced to birds imported from South America. During recent years a number of limited epidemics have been reported from different parts of the United States.

Psittacosis is essentially a household disease, the spread of the infection being limited in most instances to the family or group in contact with the infected bird.

Transmission. The etiological virus of psittacosis is present in the discharges from the nose and mouth and in the feces of infected birds. The infection is transmitted to man by contact with infected birds, or with material soiled by the infected discharges or excreta of birds. Apparently, the infection may

be air-borne in dried, dust-like material shaken from the feathers of infected birds.

The virus is also present in the sputum from human cases, and, theoretically, the infection can be transmitted from person to person in the sputum. Actually, the disease is seldom transmitted in this manner.

The virus is very infectious for man and apparently only slight and transient exposure is required to transmit the disease from birds to man.

Apparently, healthy birds may carry the infection and transmit it to man, although usually the sick bird is the source of infection.

Where psittacosis has occurred in the United States, the infection has usually been transmitted by recently imported birds, although in some instances the disease has been acquired by contact with birds, especially parrakeets, that have been reared in aviaries in this country.

Control. The prevention of psittacosis in man depends upon avoiding contact with infected birds. The general measures for preventing the spread of the disease comprise those designed to prohibit or to control the importation of susceptible birds and the supervision and control of aviaries dealing in parrots, parrakeets or canaries.

PULMONARY TUBERCULOSIS

Pulmonary tuberculosis is an important disease among troops, but its importance is due principally to the disability it produces and the burden placed on the hospitals by the necessity of caring for patients with tuberculosis.

From a strictly disease control point of view, measures to prevent the spread of pulmonary tuberculosis among troops do not constitute an important phase of military preventive medicine. The control of pulmonary tuberculosis in a military force is largely a question of preventing the entry into the service of men having the disease, and the early diagnosis and proper treatment of cases which develop, or are discovered, after entry into the service. The physical examination for enlistment or a commission is the most important control agency and should be so performed as to detect any signs or symptoms of active tuberculosis.

The ordinary military environment is not conducive to the development of active pulmonary tuberculosis and the high group resistance of the troops mitigates against the spread of the infection. Any case of tuberculosis, or any person suspected of having the disease in an active form, should be removed to a hospital for observation and treatment. In hospital, the usual precautions should be taken to prevent the spread of the infection by contact. As a rule, no specific control measures are indicated.

PULMONARY PLAGUE

The control of pulmonary plague is considered under the control of plague (Chapter XX).

CHAPTER IV.

HOUSING OF TROOPS

The principal housing factors concerned in the spread of disease are ventilation, crowding, heating, lighting, screening and plumbing. Ventilation, crowding and heating are interdependent in the creation of conditions which influence the spread of respiratory disease. The sanitary significance of plumbing is discussed in connection with the control of intestinal diseases (Chapter XIII). Screening as a factor in housing of troops is considered in Chapter XXI under the control of mosquitoes. The effect which lighting may have on the health of troops results mainly from the influence which lighting may have on the morale of the troops or on the general sanitary conditions of buildings. In the performance of certain duties, poor illumination may cause impairment of vision.

The Quartermaster Corps is responsible for the construction, repair, heating and lighting of all buildings. Unit commanders are responsible for the maintenance of proper sanitary conditions in all barracks, quarters, or tents occupied by their troops. Officers in charge of buildings used for recreation purposes, or as post exchanges, store rooms, schools, offices or other similar activities are responsible for the sanitation of such buildings.

Sanitary control. The Medical Department is responsible for the sanitary inspection and supervision of all buildings used for military purposes.

The scope of the sanitary control exercised by the Medical Department in the housing of troops includes the following activities:

1. The study of plans for the construction of buildings and the submission of recommendations relative to the adequacy of plans for heating, ventilating, lighting, screening, and the plumbing system of such buildings.
2. The sanitary inspection of existing buildings and tents and the rendition of reports on and recommendations for the correction of conditions inimical to the health of troops.

VENTILATION

Ventilation is the process of adjusting the atmospheric conditions in an enclosed space so as to meet the requirements of bodily comfort and maintain physical efficiency.

The air conditions which are considered in ventilation are temperature, humidity, movement of the air, presence of pathogenic organisms and viruses, dust content, and odors. From a practical viewpoint, no adjustment of the oxygen and carbon dioxide content of the air is required in the ventilation of barracks and other military buildings, as the alteration in the proportion of these constituents resulting from human occupancy is not sufficient to influence the physiological activities of the human body. Ventilation is, therefore, concerned principally with the changes in the physical characteristics of the air, that is, in changes in the temperature and humidity which result from occupancy of rooms and buildings by human beings.

Effect of air conditions on the human body. The influence which may be exerted by atmospheric conditions on the physiological processes of the human body is due to the combined effect of the temperature, humidity and movement of the air. In ventilation, these three conditions are interdependent to a degree which renders it necessary to consider them as one rather than as separate factors, in so far as their adjustment and the effect of that adjustment on health and comfort are concerned.

Air conditions affect health and comfort by their influence on, or interference with, the heat regulating mechanism of the body. The heat produced by the metabolic processes of the body is utilized to maintain a normal body temperature,

the excess being eliminated by conduction, radiation and convection, and by evaporation of moisture from the skin and lungs. Radiation is controlled by the temperature of the surrounding air; convection by the temperature and movement of the air, and conduction and evaporation by the humidity and temperature of the air.

Humidity. The term humidity refers to the moisture content or water vapor constituent of the air. As the water vapor is mechanically mixed with other gases of the air, it has its own partial pressure independent of the partial pressures of the other gases. Consequently, a given space at a given temperature will hold a maximum quantity of water vapor independent of the presence or absence of air. When a space is saturated with water vapor, that is, when the greatest number of molecules which can occupy the space are present, the air is said to be saturated. Under these conditions, the space which is occupied in common by the air and water vapor contains the maximum weight of water vapor which it can retain without condensation at the existing temperature. If the temperature of saturated air decreases, the partial pressure of the water vapor also decreases and a part of the contained water vapor condenses as dew. The temperature at which precipitation occurs is known as the dew point. If the temperature of saturated air increases, the partial pressure of the water vapor increases, and a proportionally greater quantity of water can be retained as vapor per unit of space.

Absolute humidity is the weight of water vapor in a given volume of space. It is usually stated as grains or pounds of water vapor per cubic foot.

Relative humidity is the percentage which the actual amount of aqueous vapor in a given space at the existing temperature is of the amount required to saturate the same space at the same temperature. Thus, a cubic foot of space at a temperature of 60°F. is capable of holding 5.74 grains of aqueous vapor, and if 5.74 grains are present, the relative humidity is 100 per cent. However, if only 1.72 grains are present, then the relative humidity is 30 per cent, as 1.72 is 30 per cent of 5.74.

For ventilation purposes the humidity of the air is always expressed in terms of relative humidity. This term does not, however, express the actual amount of moisture in the air but only the relative quantity. For example, a cubic foot of air may

contain 0.39 grains of aqueous vapor at 10°F.; 1.42 grains at 40°F.; 4 grains at 70°F.; or 9.9 grains at 100°F., but the relative humidity would remain constant at 50 per cent.

A number of different procedures and appliances may be employed to determine the relative humidity, but all are based on the temperature of evaporation, which is the difference between a wet bulb and a dry bulb temperature (Fig. No. 5). The difference between the wet bulb and dry bulb temperatures depends on the amount of moisture evaporated from the covering of the wet bulb, which is in turn governed by the humidity of the air. In saturated air, no evaporation occurs and the wet and dry bulb temperatures are the same.

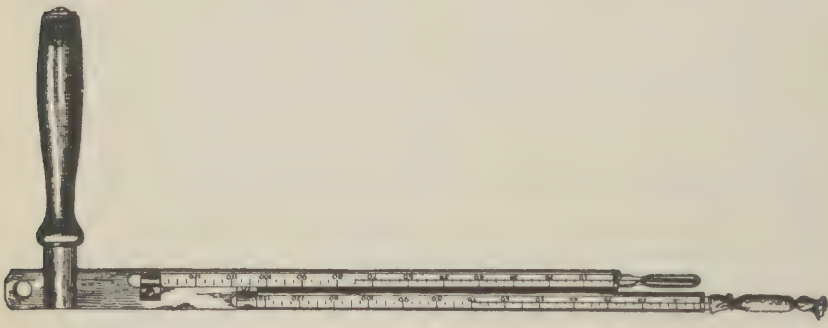


FIG. No. 5. A sling psychrometer.

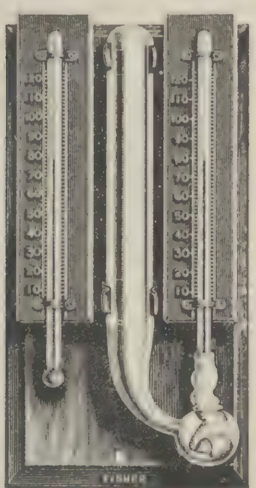
The sling psychrometer (Fig. No. 5). The sling psychrometer may be used to determine the relative humidity. It consists of two thermometers attached to a single back which is equipped with a handle so that the whole apparatus can be whirled rapidly through the air. The lower of the two thermometers is converted into a wet bulb by tying a piece of thin, washed muslin tightly over the bulb and wetting with clean water, the temperature of which is somewhat above the wet-bulb temperature of the air.

The thermometers are whirled rapidly for about 20 seconds and the whirling stopped to permit the thermometers to be read. This is done as quickly as possible, the wet bulb thermometer being read first. A mental note is made of the readings and the thermometers immediately whirled again for 20 seconds and a second observation taken. The operation is repeated until the wet bulb temperature is approximately constant for two or

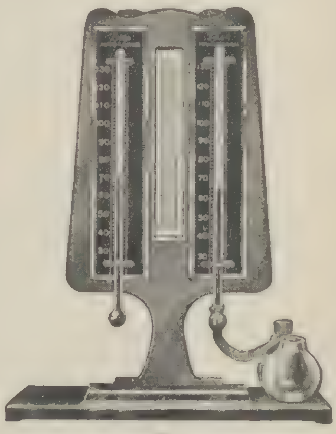
more consecutive readings. The dry bulb and the wet bulb readings are then applied to a psychrometric chart (Fig. No. 8) and the relative humidity determined.

Relative humidity determination should be made in the shade and, if out of doors, the operator should stand facing the wind and whirl the apparatus in front of his body.

The psychrometric chart is used as in the following example. Assuming a dry bulb temperature of 70° F. and a wet bulb of 58.5° F., the vertical line on the chart representing the dry bulb temperature of 70° F., is traced to the point where it intersects the diagonal line passing downward and to the right which represents a wet bulb temperature of 58.5° F. From this point, the relative humidity curve is followed upward and to the right to the right margin of the chart and the relative humidity read off, which, in this example, would be 50 per cent.



A.



B.

FIG. No. 6. A— Hygrometer, Mason, showing wet and dry bulb thermometers. (Courtesy of the Fisher Scientific Co., Pittsburgh, Pa.).

B— Hydro-Autometer Hygrometer. Relative humidity is determined directly by means of a revolving paper chart placed between the wet bulb and dry bulb thermometers. (Courtesy of Eimer and Amend, New York, N. Y.).

Instruments other than the sling psychrometer are available for determining relative humidity. Some of these record dry-bulb and wet-bulb temperatures and others record the relative humidity directly (Fig. No. 6). In using a stationary apparatus

the necessary air movement is usually produced by means of a fan.

Air movement. The movement of the air surrounding the body influences the loss of heat by convection and evaporation. Body heat is lost by convection as long as the temperature of the air in contact with the body is less than the temperature of the skin and lungs, and by evaporation while the relative humidity is less than 100 per cent and the atmospheric temperature is more than about 50°F. Movement of saturated air having a temperature of 98.6°F., or more, has no effect on the elimination of body heat.

The layer of air surrounding the body and in contact with the skin and clothes absorbs the moisture evaporated from the skin and lungs and the heat transferred to it from the body. Consequently, if this air is not moved away from contact with the body, it becomes saturated with moisture and the temperature rises to that of the body, when no further elimination of heat by convection and evaporation is possible. If, however, the air is moving, the air containing heat and moisture is transported away from the body and replaced with that which is cooler and dryer. Thus, air movement is an essential factor in the ventilation of an inhabited enclosed space in order to prevent increase in the humidity and temperature of the atmosphere by the moisture and heat eliminated by the bodies of the occupants.

Effect of air conditions on heat loss. The influence of the atmospheric temperature on the elimination of heat from the body is modified by the relative humidity. The moisture in the air serves to conduct heat away from the body and also to decrease the loss of heat by evaporation of perspiration from the skin, and moisture from the lungs. Therefore, the effect of a relatively high humidity on the elimination of heat from the body is very different when the air is cool than when it is warm.

The loss of heat from the body through the evaporation of perspiration begins when the temperature of the surrounding air reaches about 50°F. Below a temperature of 50°F. the heat is eliminated by conduction, radiation and convection. Moisture is a good conductor of heat and when brought into contact with the skin either as aqueous vapor, or in clothing moistened by water from the air, it serves to conduct heat

from the body. For this reason cold air having a high relative humidity will chill the body much more rapidly than dry air at the same temperature.

When the temperature rises above 50°F. the evaporation of perspiration becomes an important factor in the elimination of the excess body heat. However, the extent and rapidity of evaporation, and therefore its cooling effect, is influenced and to a considerable extent determined by the humidity of the surrounding air which retards the evaporation of the perspiration to a degree which varies directly with the relative humidity. In still air having a relative humidity of 100 per cent, the body temperature, with the body at rest, will rise when the atmospheric temperature reaches 90°F. to 92°F., and death will occur in a few hours at a temperature of 110°F.

Effect of air conditions on physical efficiency. An overheated atmosphere causes a reduction in the ability of the human body to perform work to an extent which varies with the increase of the temperature above the optimum, the relative humidity, the clothing, and the character of the work. Long continued exposure to poor air conditions, such as occurs when troops are housed in poorly ventilated barracks, will adversely affect general physical efficiency by increasing susceptibility to fatigue.

Effect of air conditions on resistance to infection. Poor ventilation, that is, air conditions which interfere with elimination of heat from the body, tends to lower the resistance of the tissues of the respiratory tract to infection. Crowding which is a factor in producing and usually accompanies poor ventilation in squad rooms also promotes the dissemination of air-borne infections, and thus a vicious circle is established.

Determination of air conditions in occupied rooms. For practical purposes, in the inspection of occupied rooms, the existing air conditions are determined by the temperature as shown by a thermometer and the effect of the air on the senses. Overheating is evidence of poor ventilation, regardless of whether the excess heat is derived from the bodies of the occupants or from heating appliances. Given a proper temperature, a sense of discomfort as evidenced by a feeling of excessive warmth, stuffiness of the air, or lack of atmospheric freshness, particularly when the room is first entered, is in-

dicative of a high relative humidity or insufficient air movement, or both.

Instruments of precision, such as a hygrometer, the sling psychrometer, and an anemometer, are necessary aids in the

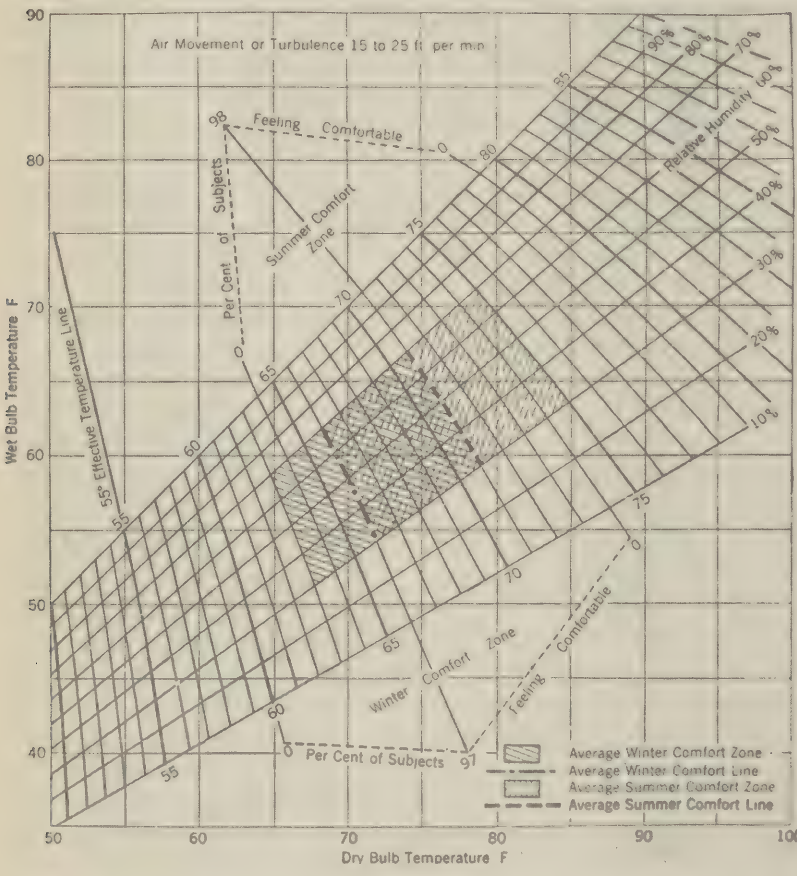


FIG. No. 7. Comfort Chart for air velocities of 15 to 25 FPM (Still Air). *Note.*—Both summer and winter comfort zones apply to inhabitants of the United States only. Application of winter comfort line is further limited to rooms heated by central station systems of the convection type. The line does not apply to rooms heated by radiant methods. Application of summer comfort line is limited to homes, offices and the like, where the occupants become fully adapted to the artificial air conditions. The line does not apply to theaters, department stores, and the like where the exposure is less than 3 hours. (Copyright—American Society of Heating and Ventilating Engineers—From A.S.H.V.E. Transactions, Vol. 38, 1932).

performance of ventilation studies or in testing ventilation systems, but are difficult to employ in the routine inspection of squad rooms and offices.

The combined effect of the temperature, humidity and air movement on the physical efficiency of the human body is measurable by the degree of bodily comfort produced by these conditions. Within limits, a high temperature with a low humidity, or a high humidity with a lower temperature, are equally comfortable, provided the air movement is sufficient to maintain them at a constant level. The temperature of the air may vary inversely with the humidity from 62°F. to 73°F. within a relative humidity range of from 30 to 70 per cent without producing discomfort due either to cold or warmth. This is the so-called *comfort zone* (Fig. No. 7). For example, the optimum comfort for the average person normally clothed during winter is produced by air conditions which represent approximately an atmospheric temperature of 72°F. and a relative humidity of 50 per cent, or an atmospheric temperature of 74°F. and a relative humidity of 30 per cent, and an air movement of 100 feet per minute. Different kinds of physical exertion and the amount and kind of clothing worn will modify greatly the air conditions required to produce comfort and a maximum degree of physical efficiency. There are also seasonal variations in the comfort zone. The temperature which will be the most comfortable for the greatest proportion of people is higher in summer than in winter.

Effective temperature. Effective temperature is a term that is frequently used to describe the condition of the air in ventilating and air conditioning work. Effective temperature is the degree of warmth or cold felt by the body in response to the combined effect of the temperature, humidity and movement of the air. It is not a true temperature but is a composite index or scale representing the combined value of the temperature, humidity and air movement. As defined by the American Society of Heating and Ventilating Engineers, the effective temperature of any given air condition corresponds to the true temperature of saturated still air (the air movement or turbulence being not more than 25 feet per minute) which induces a sensation of warmth or cold similar to that produced by the given air condition. For example, an atmosphere has an effective temperature of 70°F., regard-

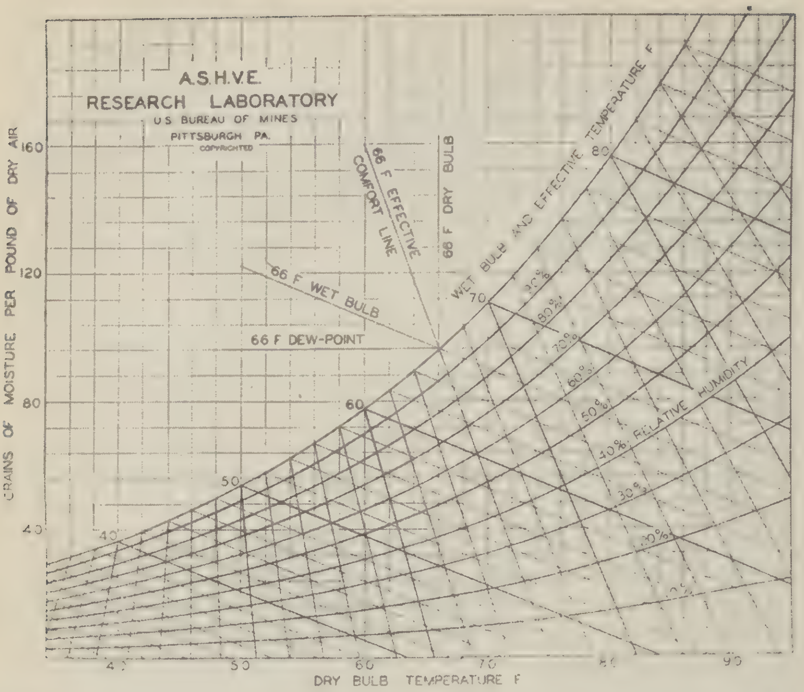


FIG. No. 8. Psychrometric chart, for persons at rest, normally clothed, in still air. (Copyright—American Society of Heating and Ventilating Engineers—From Ch. 3, A.S.H.V.E. Guide, 1936).

less of its true temperature, when it produces the same feeling of warmth as that felt in still air at a dry bulb temperature of 70°F. and a relative humidity of 100 per cent. However, as shown in Fig. No. 8, if the relative humidity is reduced to 50 per cent, the dry bulb temperature of air must be raised to 75°F. in order to maintain an effective temperature of 70°F. Or if the air movement is increased to 100 feet per minute and the relative humidity remains at 50 per cent, then the dry bulb temperature must be raised to 77°F. to hold the effective temperature at 70°F. (Fig. No. 9). If the dry bulb temperature remains at 75°F., the relative humidity at 50 per cent and the air movement at 100 feet per minute, the effective temperature will be 68.8°F.

The effective temperature is not a measure of comfort but is only a comparative index. According to the findings of the American Society of Heating and Ventilating Engineers, the average winter comfort zone ranges from 63°F. to 71°F.

effective temperature and the optimum effective temperature is 66°F. Also, according to the same findings, the average summer comfort zone for exposure of three hours or more is between 66°F. and 75°F. effective temperature and the probable optimum effective temperature is 71°F.

Ventilation requirements. For practical purposes the adequacy of ventilation is determined by its effect on the physical characteristics of the air and not on changes in its chemical constituents. The proper ventilation of an occupied room

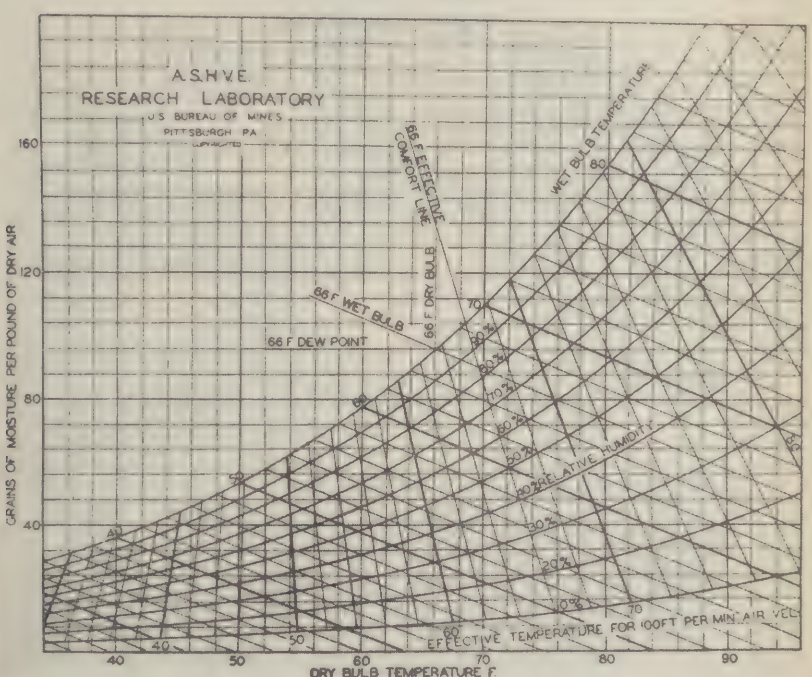


FIG. No. 9. Psychrometric chart, persons at rest, normally clothed, in 100 FPM air velocity. (Copyright—American Society of Heating and Ventilating Engineers—From Ch. 3, A.S.H.V.E. Guide, 1936).

requires that the air be moved through the room, that is, admitted and removed, in such volume and with such velocity that the dry bulb temperature and the relative humidity will remain approximately constant within the *comfort zone* without the production of drafts that are uncomfortable to the occupants of the room.

Volume of air required. In buildings utilized for military purposes, such as barracks, storerooms, offices, and quarters, the control of the volume of air required for suitable ventilation is not usually a serious problem, but control of the velocity of the air currents and the elimination or prevention of undesirable drafts may present many difficulties. The volume of air required to ventilate a given space depends within limits on the size and shape of the space in question, the number and activities of the occupants and the difference in the temperature of the inflowing air and the air of the room. Under average conditions, and when there is no considerable

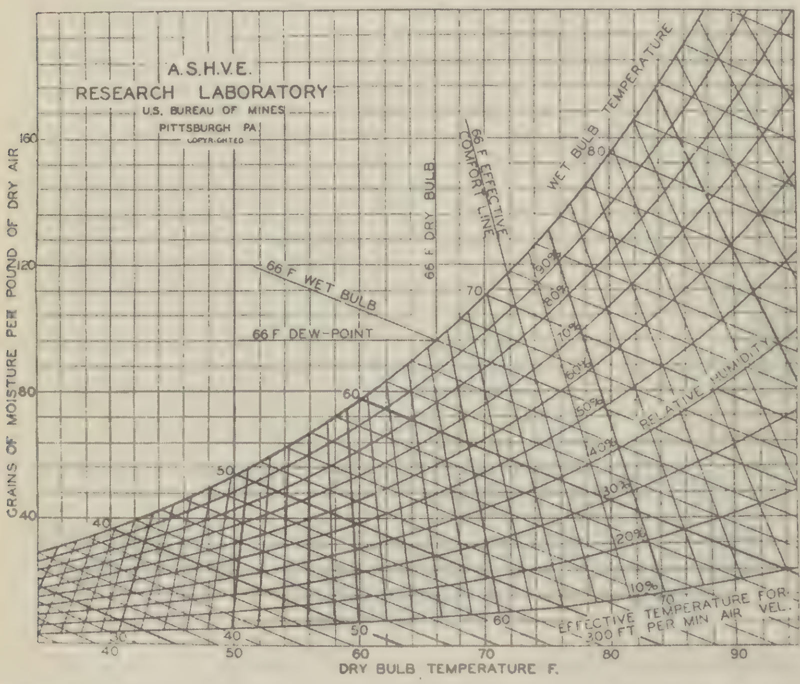


FIG. No. 10. Psychrometric chart, persons at rest, normally clothed, in 300 FPM air velocity. (Copyright—American Society of Heating and Ventilating Engineers—From Ch. 3, A.S.H.V.E. Guide, 1936).

difference between outdoor and indoor temperatures, a barracks which provides from 600 to 720 cubic feet of air space per man will require at night, when the occupants are sleeping, from 1800 to 2200 cubic feet of fresh air per man per hour, or three changes of air per hour. The same barracks during

the day, when it is occupied by only a few men off duty or in charge of quarters, may be adequately ventilated by a much smaller volume of exchange air. Under similar conditions in offices and in hospitals, 3000 cubic feet of air per person per hour should be provided.

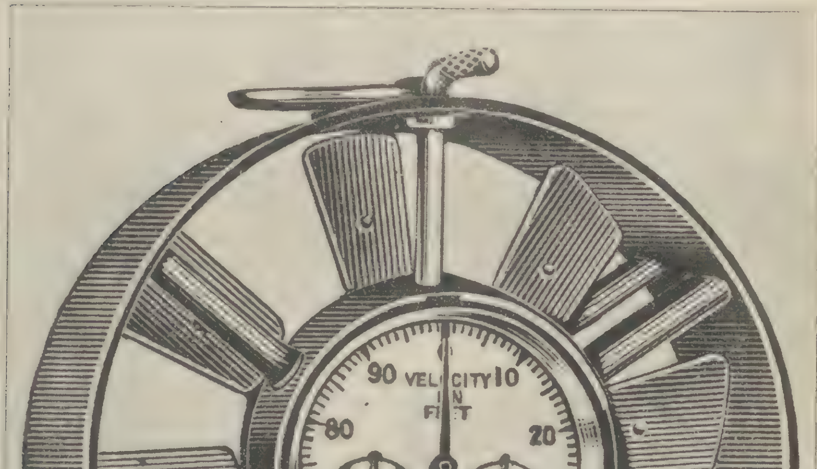


FIG. No. 11. Anemometer, Biram Pattern, for determining velocity of air currents. (Courtesy of the Arthur H. Thomas Co., Philadelphia, Pa.).

Velocity of the air. The velocity of an air current required to produce a draft depends somewhat on the difference in the temperature of the surrounding still air and the moving air. With both the still air and the current air at room tem-

perature, a velocity of about two feet per second is perceptible and a velocity of about four feet per second will produce a definite draft. Drafts are caused by lower velocities where the current air is colder than the still air.

The rate of flow and the direction of low velocity air currents can be roughly determined by the use of smoke from a cigarette or taper. An anemometer similar to the instrument shown in Fig. No. 11, may be used to obtain more exact measurements in the study of ventilating systems.

Natural ventilation. Natural ventilation is a process by which an interchange of indoor and outdoor air is effected through openings in the walls of the space in question without the aid of mechanical devices. Where a room is ventilated by natural ventilation, the air currents pass through open windows and doors, through cracks around the windows and doors and in the walls, floors, ceilings and roofs, or through air inlets and outlets, such as roof ventilators, gravity exhaust ducts or registers.

The effectiveness of natural ventilation in producing air currents depends on gravity circulation due to differences in temperature, and on perflation, aspiration and diffusion. Warm air tends to rise and displace the colder air above. The difference in temperature between strata of air is the principal factor in the movement of air within an occupied room and, where the outdoor air is colder than the indoor air, exerts a determining influence on the velocity of the air flowing into and out of a room. Perflation is the movement of air into a room by the force of the wind. Aspiration is the extraction of air from a room by the suction produced by the wind blowing across the mouth of an opening, such as a chimney or exhaust duct, or past an open window.

In the absence of fans or blowers to propel the air, the flow of air within a room is governed by the difference in temperature, the warm air rising and replacing an upper and cooler stratum. During the colder months of the year, when the ventilation of barracks becomes a difficult problem, the outdoor air is colder than the indoor air. Consequently, when the cold air is admitted to a room, it remains near the floor until warmed to the temperature of the air in the room when it rises to be replaced by a fresh supply of colder air.

In order to produce a current of air through a room by natural ventilation, it is necessary that openings be provided for the admission of the cold outdoor air and for the exit of the warm indoor air. A single opening, such as an open window, will not suffice, as air will enter a building, either as a result of pressure or difference in temperature, only when provision is made for the removal of a corresponding amount of air. The adequacy of natural ventilation therefore depends on the presence of properly located and controlled inlets and outlets of suitable capacity.

Inlets and outlets. In the ventilation of a room by natural ventilation there should be at least two openings, one of which is at a higher level than the other, so as to facilitate the circulation of the air through the room by difference in gravity. The upper opening becomes the outlet for the warmer and lighter room air, while the lower opening serves to admit the colder and heavier outdoor air to replace that removed through the upper openings.

If the outdoor air is colder than that indoors, the most complete and uniform removal of air from the room is obtained when the inlet is placed near the floor on one side of the room and the outlet near the ceiling, on the other side. If both openings are near the floor or near the ceiling, the flow of air throughout the room is not uniform and is decreased in volume because, as the inlet and outlet are at the same level, there is no difference in temperature between them. When the outlet and inlet are on the same side of the room, the flow of air is short circuited so that the air in the more distant parts of the room is not removed.

The area of the controlled openings required to provide a satisfactory air movement through a room depends largely on the degree of crowding in the room, the difference in temperature between the indoor and outdoor air, the velocity and direction of the wind, and the permeability of the walls, floors and ceiling or roof of the room or building. However, as a point of departure in determining the total area of the inlets and outlets, it may be considered that in the case of an ordinary permanent barracks utilized for sleeping quarters, from 1 to 1.5 square feet of inlet and outlet surface will be required for every ten men when the outside temperature is about

50°F., provided there is a perceptible breeze out of doors and no undue crowding or overheating indoors.

The greatest difficulty in the operation of a natural ventilation system is encountered in the prevention of drafts due to the velocity of the inflowing air which, because of the low position of the inlets, strikes the occupants of the room before being warmed. The velocity of the air currents may be decreased and drafts prevented by the use of a large number of relatively small inlets rather than a few larger openings. Thus, fewer uncomfortable drafts will occur in a squad room when a number of windows are slightly opened than when one or two are widely opened.

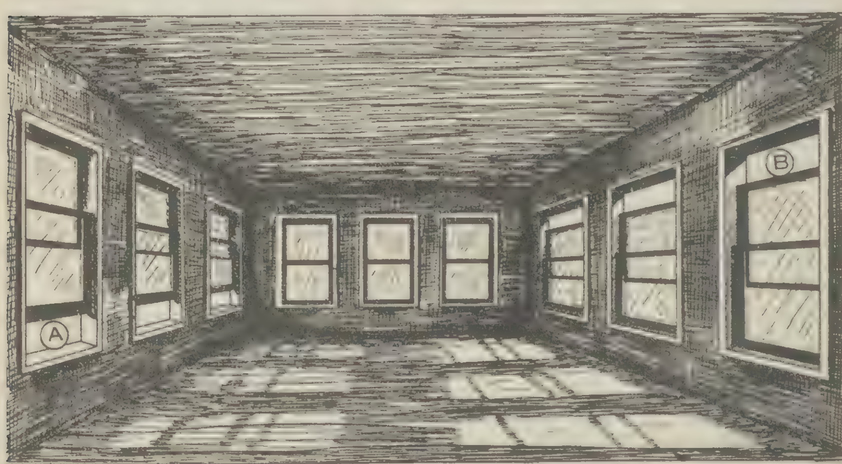


FIG. No. 12. Ventilation of squad rooms showing method of arranging window openings. A—Inlet. B—Outlet..

Window ventilation. The simplest method of obtaining natural ventilation in barracks, office buildings or quarters is by the manipulation of the windows so as to produce inlets and outlets of proper size and suitably located. The ordinary squad room can be most effectively ventilated by means of vertically sliding double sash windows opened from the bottom on the windward side of the room and from the top on the other side (Fig. No. 12). Swinging windows provide ventilation through the openings at the top and bottom.

Where a room has windows on one side only, the outlets may consist of roof ventilators or, in the case of buildings having more than one story, of gravity exhaust ducts.

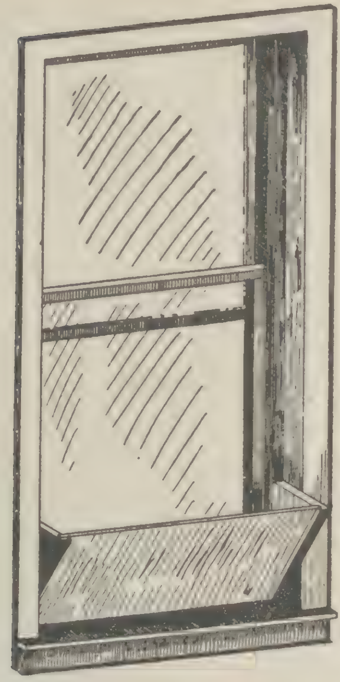


FIG. No. 13. Simple window board ventilator.

In cold weather, barracks may frequently be adequately ventilated in the daytime by opening the windows only at the top and allowing cracks in walls and floors, and the doors as they are opened and closed, to serve as inlets.

Window board deflectors. The creation of drafts by window inlets can be avoided to some extent by the use of wooden or glass deflectors. These may be installed as shown in Fig. No. 13 and consist of a board or a panel of glass, 12 to 18 inches in width, fastened across the lower end of the window frame so that there is a space of several inches between the deflector and the window sash. The inflowing air strikes the outer surface of the deflector and is deflected upward so that it does not blow directly on the occupants of the room.

In buildings heated by steam or hot water, the radiators may be placed immediately beneath the windows so that the current of warm air rising from a radiator will carry upward the colder outside air flowing through the open window.

Window board deflectors should be used to prevent the escape of the warmed air through window inlets (Fig. No. 14).

Register inlets. Register inlets consist essentially of an opening through the wall in which adjustable shutters are placed. These shutters serve to control the size of the opening and the volume of air admitted to the room. The register inlets are usually placed in the walls near the floor.

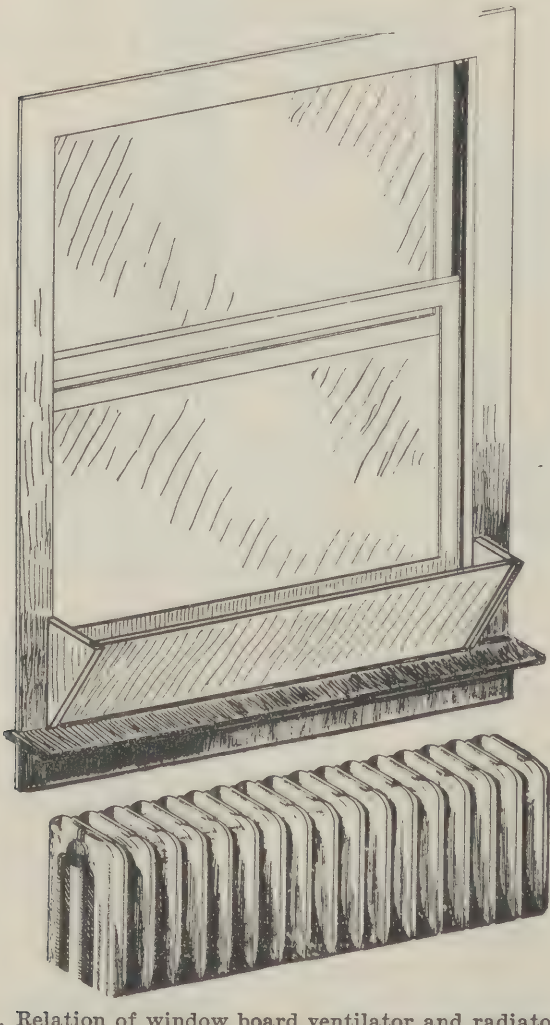


FIG. No. 14. Relation of window board ventilator and radiator in the ventilation of barracks.

Roof ventilators. A roof ventilator is a stack or pipe rising from the roof of a building which serves as a gravity exhaust vent for the space below. In the case of barracks, it usually projects upward from the ridge section of the roof for a distance of from one to three or four feet.

Roof ventilators may be round, square, or rectangular. They may be made of wood or metal and ordinarily are equipped with cowls and with shutters or louvres which can be adjusted by means of cords or pulleys (Fig. No. 15). The number and size of the ventilators for any one building will vary with the average ventilation demand.

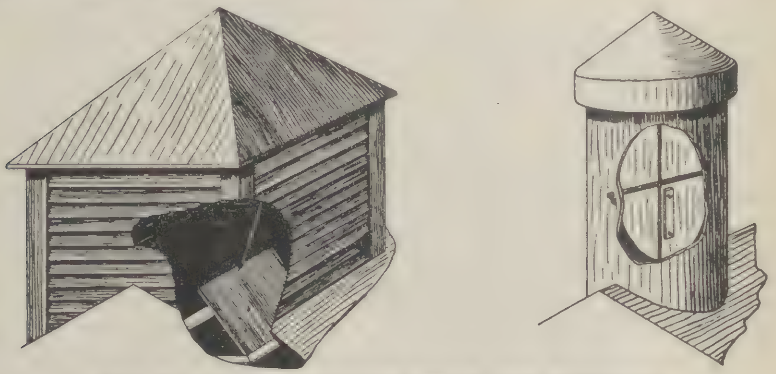


FIG. No. 15. Two common types of roof ventilators.

A roof ventilator is usually from 18 to 24 inches square. The combined area of the roof ventilators for a room or building should be commensurate with the average area of the air inlets.

In a single story, unceiled barracks, the roof ventilator opens directly into the squad rooms and gravity exhaust ducts are not required (*infra*). In ceiled squad rooms, ceiling vents or exhaust ducts are employed to remove the air from the room into the space below the roof ventilators. In the case of barracks having more than one story, the outflowing air is conducted from all squad rooms to the roof ventilator by exhaust ducts.

Gravity exhaust ducts. A gravity exhaust duct is a shaft which extends from near the top of the wall or from the ceiling of a room to the outside air. It usually passes upward through the roof, or into the space below a roof in which roof ventilators are installed. The size and number of ducts required depend on the size and shape of the room, but the com-

bined horizontal area should approximate the area of the inlets, that is, under average conditions, it should be from 1 to 1.5 square feet for every ten men quartered in the room.

Gravity exhaust ducts are not ordinarily employed where it is practicable to obtain window ventilation from two sides of a room. They can be used to an advantage in a room having windows on one side or in one in which the windows are located only in the lower part of the walls.

The removal of air from a room through a gravity exhaust duct is governed by the difference in temperature between the outdoor and indoor air. The warmer room air rises through the duct and is replaced by the cooler outdoor air admitted through the inlets below. The gravity exhaust duct should, therefore, be within the building until it passes through the roof in order to prevent chilling of the air in transit, and consequent retardation of the flow.

Control of natural ventilation. From a practical point of view, the principal factors in ventilation are temperature and drafts. The proper control of natural ventilation involves the maintenance of suitable temperature without producing uncomfortable or chilling drafts. Consequently, every squad room should be equipped with a wall thermometer.

In the ventilation of barracks by natural ventilation, the responsibility for the maintenance of proper air conditions rests with the unit commander. Good discipline, enforced by constant supervision and frequent inspections, is essential in preventing troops in barracks from closing or reducing the area of air inlets whenever the temperature of the outdoor air is less than the room temperature. Under such conditions, the temperature and relative humidity of the indoor air will rise to, and be maintained at a point which may prove detrimental to the health of the occupants.

In practice, noncommissioned officers must be taught the need of ventilation and the methods of maintaining proper air conditions within barracks. Otherwise, any system of natural ventilation adopted will fail to accomplish its purpose.

Mechanical ventilation. Mechanical ventilation is a process by which air is forced into or drawn out of a room, or both, by mechanical means. A mechanical system of ventilation consists of a plenum system, or a vacuum system, or a combined plenum and vacuum system.

The plenum system. A plenum system forces the air into a room through ducts by means of fans or blowers and the resulting increase in pressure causes the air to escape from the room through roof ventilators, exhaust ducts or other openings. The incoming air may be warmed by being passed over heating coils; moisture may be added or the air may be washed in spray chambers; moisture may be removed from the air by baffle plates, or dust may be eliminated by screens or filters.

The vacuum system. A vacuum system removes air from a room by means of a fan or blower. The decreased pressure within the room causes the outdoor air to enter through windows, ducts or other openings.

The combined vacuum and plenum system. The combined vacuum and plenum system of ventilation provides mechanical means for forcing conditioned air into a room and for removing air in definite amounts at a definite rate.

Efficiency of mechanical ventilation. Mechanical ventilation is frequently a most effective method of ventilating large buildings, such as theaters, office buildings or schools. It is not ordinarily employed in the ventilation of barracks or quarters.

Air conditioning. Air conditioning is the process of controlling the temperature, humidity and movement of the air in a room or other enclosed space by means of heating, cooling, humidifying and dehumidifying devices. Air conditioning may also include the removal of odors, dust, gases or fumes. The conditioned air is recirculated with the addition of a varying proportion of outside air.

In the military service, air conditioning has been utilized in the ventilation of operating rooms in hospitals and in certain other special situations. It has not been found to be practicable to employ air conditioning in the ventilation of barracks. The science of air conditioning is making rapid progress and it is probable that it will be employed to a much greater extent in military buildings in the future.

BED SPACING

A certain minimum amount of floor and air space must be provided for each bed in a squad room, in order, first, to prevent actual crowding which would raise the atmospheric temperature or relative humidity in the immediate vicinity of

the occupants of the beds, and, second, to minimize the transmission of pathogenic organisms by air from one man to another (page 32). Bed spacing and ventilation are, within limits, interdependent factors in determining the effect which air conditions will have on the health of troops in barracks. However, wide spacing of beds will not compensate for poor ventilation, nor will good ventilation neutralize the bad effects of inadequate bed spacing.

Improper spacing of beds will produce unfavorable air conditions which cannot be removed by air movement without the creation of undesirable drafts. Also, if beds are grouped too closely together, even though there is ample space in the room and the ventilation is adequate, the transmission of large numbers of pathogenic organisms by air from the occupant of one bed to a man in another bed is facilitated.

Space for each bed. Under average conditions, a minimum of 60 square feet of floor space should be allotted for each bed exclusive of that occupied by furniture or fixtures other than the bed and foot locker. The calculation or measurement of minimum floor space should not include any that extends to a distance of more than four feet from either end of the bed. In an emergency, the minimum floor space may be reduced temporarily to 50 square feet per bed, provided there is adequate ventilation.

The space allotted for each bed in a given room should be used so as to secure the greatest distance between the beds. Where only 60 square feet is available, the ideal arrangement is a space six feet wide and ten feet long for each bed, the beds being placed six feet apart from center to center.

Beds should never be grouped in order to obtain space for other purposes, where grouping will reduce the actual amount of space occupied by each bed to less than 60 square feet. Thus, a squad room 20 feet wide and 36 feet long (720 square feet) has a capacity of 12 beds, if all the floor space is used for beds. If space is needed in this room for other purposes, such as recreation or wall lockers, it should be obtained by reducing the number of beds and not by crowding the beds together.

In order to reduce the transmission of pathogenic organisms by air from one man to another, the beds should be placed so as to obtain the greatest distance between the faces of the occupants.

Where the side bars of the beds are less than five feet apart, the beds should be so arranged that the head of each bed is opposite the foot of each adjacent bed (Fig. No. 16). Where the shape of the space permits, a still greater distance between the faces of the occupants of adjacent beds can be obtained by staggering the beds.

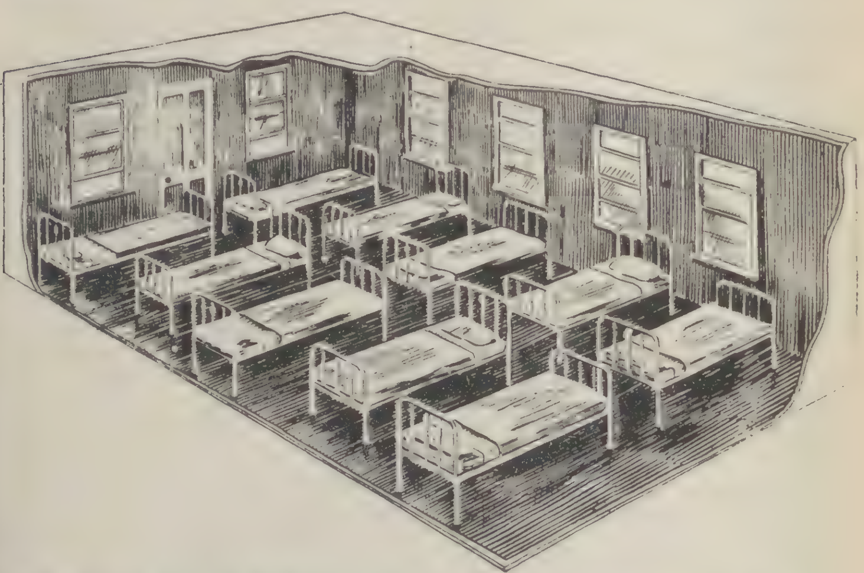


FIG. No. 16. A method of arranging beds in squad room showing head and foot arrangement.

Number of beds in a room. The number of occupied beds in a squad room, regardless of spacing, is also an important factor in the spread of respiratory disease. In the event that one of the occupants of a squad room contracts a respiratory disease or becomes a carrier, the number of exposures increases directly with the number of men sleeping in the room. Consequently, squad rooms should, within limits, be as small as practicable and one room should not contain more than 30 beds.

TENTAGE

Given suitable climatic conditions, respiratory diseases are, as a rule, less prevalent among troops housed in pyramidal tents, or tents of similar size, than among those living

in barracks. This is due mainly to the fact that a much smaller number of men are housed in one tent than in the average squad room and the exposure rate is, comparatively, much reduced. The diminished chances of exposure compensate in a measure for the reduction in floor and air space.

Tents have the great disadvantage, however, that they are difficult to heat and ventilate in cold weather and the occupants are usually exposed to either an overheated or a chilling atmosphere.

If tents are to be occupied for any considerable length of time, they should be provided with floors and frames, as shown in Fig. No. 17.

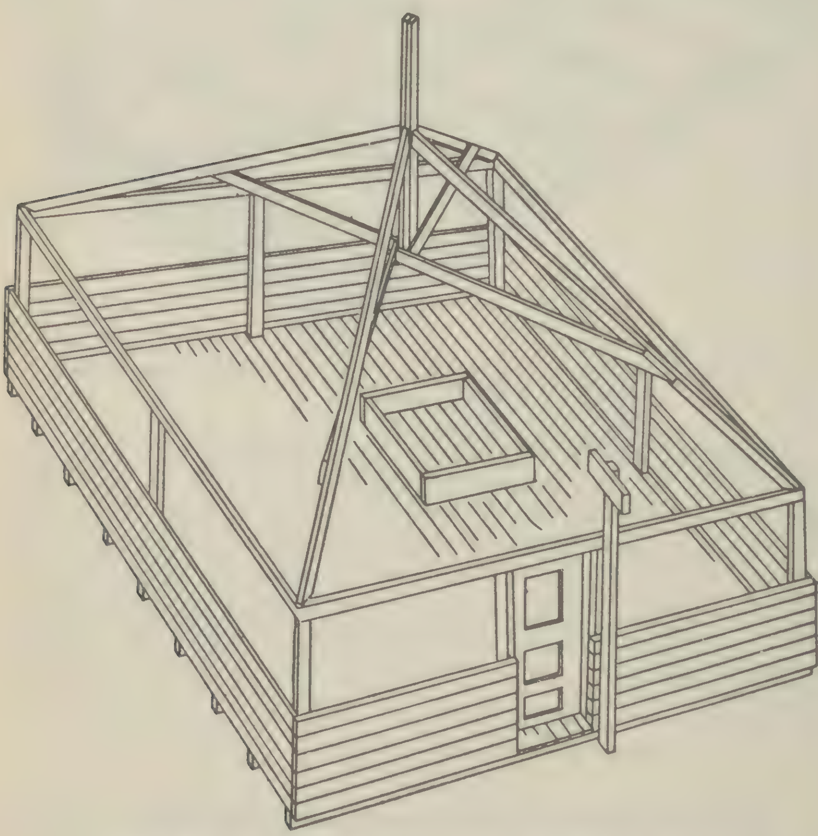


FIG. No. 17. Floor and frame for pyramidal tent.

Capacity of the standard pyramidal tent. The pyramidal tent has a floor area of approximately 250 square feet. The walls are 6 feet 4 inches and the peak 15 feet 6 inches high. Not more than six men should be housed in one tent under average conditions and the number should be reduced to not more than five in the presence of an epidemic of respiratory disease.

Ventilation and heating of tents. All tents should be well ventilated when occupied. The peak of the pyramidal tent should be kept open and provision made for admitting air around the bottom of the tent. Wall or shelter tents should be at least partially open at front and rear.

The interior of all tents should be thoroughly aired daily. The sides of pyramidal tents should be furled and the front and rear of wall and shelter tents opened widely. All tents that do not have floors should be struck at least once each week and the sites exposed to the air and, if weather conditions permit, to sunshine.

Where necessary pyramidal or wall tents are heated by stoves (page 144). Usually, the small coal or wood, sheet iron stove, or the so-called Sibley stove, is used. Tents quickly become damp and uncomfortable in cold, wet weather and, if they are to be occupied for any considerable length of time, they should be heated. Particular attention must be given to the ventilation of heated tents.

HEATING

The effect of overheated air in occupied rooms is considered under ventilation (*supra*). Underheated air is detrimental to the health of the occupants of a building, in that it exposes them to chilling with consequent lowering of resistance to infection.

Methods of heating. The source of artificial heat may be a stove, radiator, fireplace, or gas or electric heaters within the room to be heated, or a hot air furnace outside the room. The heat is delivered mainly by radiation or convection. The heat from a hot air furnace is supplied to the room by convection only, and that from a fireplace by radiation only. A radiator within the room heats the air by both radiation and convection.

In general, the methods of heating are classified as direct, indirect, or direct-indirect. The direct method consists of heating the air in a room directly from heat sources such as stoves, radiators, or fireplaces, which are located within the rooms. In the indirect method, a source of heat, such as a hot air furnace, hot water pipes, steam coils or radiators, is located outside the room and the preheated air is forced by gravity circulation, fans or blowers through ducts into the rooms to be heated. The direct-indirect method consists of some combination of direct and indirect methods, such as for example the use of direct radiators in the rooms and indirect radiators in the basement with ducts leading to the rooms to be heated.

Steam and hot water radiators. The most practicable and the most common method of heating the type of buildings used in the military service is directly by steam or hot water radiators. The hot water method has the advantage that a more uniform temperature can be maintained in the room. A larger proportion of the heat is given off by convection than in the case of steam heated radiators and therefore the air is more comfortable. A steam heating system will deliver heat much more quickly than a hot water system. This is due to the fact that the steam is under positive pressure, while the circulation of the heated water in a hot water system is accomplished by gravity.

The indirect or direct-indirect methods of heating are seldom used in military buildings.

Stoves. Stoves are used to heat tents where heating is required and practicable. Stoves may also be employed to heat temporary buildings. Usually, the ordinary coal stove is used in buildings, and a small coal stove or a Sibley stove in tents.

Stove heating is the least desirable method of heating barracks. As a rule, the air in the vicinity of the stove is overheated while that in the more distant parts of the room is insufficiently heated. Also, in cold weather, the occupants of the room tend to crowd together near the stove with the result that opportunities for the transmission of the infective agents of respiratory diseases are greatly increased.

LIGHTING

The lighting of squad rooms, day rooms, libraries, school rooms, etc., has an indirect influence on the health and physical efficiency of troops, even though poor lighting is not an immediate source of disease. Light, particularly direct sunlight, exerts a bactericidal effect. Thus, insufficient light in a squad room, by creating conditions in which bacteria may live for a longer period of time, may serve to facilitate the spread of pathogenic organisms which would otherwise be quickly killed in an adequately lighted room. Poorly lighted squad rooms, recreation or reading rooms have a depressing effect which may influence adversely the morale of the troops. In the performance of specialized duties such as clerical work, drafting, or printing, sufficient illumination is essential in order to prevent impairment of vision.

Standards of measurement. Light is the source of illumination and illumination is the volume of light derived from a luminous source and received on a surface.

Intensity of the light source. The standard unit of intensity, or candle-power, accepted as such by the national authorities of the United States, Great Britain and France, is a candle which produces an approximately uniform illumination and is known as the "international candle". The ordinary electric light bulb has a luminous intensity of approximately one candle power for each watt consumed.

Intensity of illumination. The unit of intensity of illumination is expressed as a foot candle. A foot candle is the illumination received through a transparent medium at a point one foot distant from a source of light of one candle power.

Reflection. The light received by a surface is either absorbed or reflected. The light striking a surface is known as the incident light and that reflected as the reflected light, the latter giving brightness to the reflecting surface. The reflection factor is the ratio of the reflected light to the incident light.

There are three types of reflection,—specular, diffuse and composite. Specular reflection results when the incident light strikes a mirror-like surface and the reflected rays are parallel. When the incident light falls on a dull surface, the re-

flected rays are diffused to all possible angles, producing diffuse reflection.

Usually, however, when the incident light strikes a surface both specular and diffuse reflection occur. This is called composite reflection and is the most common type.

The reflection factors of various paints used on ceilings and walls is determined by the color. Gardner's table of reflection factors for certain paints is as follows:-

	Reflection factor (per cent)
Gloss mill white	74 - 82
Flat mill white	78
Light cream	74
Light yellow	65
Light buff	58
Light gray	49
Light green	47
Medium gray	30
Medium green	16
Red	13
Dark blue	13
Dark brown	13
Dark green	12

In the illumination of rooms, the reflection of light from the ceiling and walls is a very important factor, particularly in the case of natural illumination and semi-indirect and total indirect artificial illumination. The successive reflection of the light from the reflecting surfaces within the room increases the illumination derived from the source until all the reflected light is absorbed. Consequently, the reflecting power of the walls and ceiling of a room will materially influence the intensity of the illumination produced by a given light source.

Methods of light measurement (*photometry*). The intensity of a source of light or the illumination at a given point may be measured by comparing the intensity of the light to be measured with a standard light source of known intensity. While different appliances are employed to measure illumination, the foot-candle meter (Fig. No. 18) is sufficiently accurate for the purpose of conducting such lighting studies as may be required in the military service. The foot-candle meter is best suited for the measurement of illumination produced by artificial lighting where the illumination is not more than 20 foot candles.

FIG. No. 18. Photometer measuring directly in foot candles. (Courtesy of the Weston Electrical Instrument Corporation, Newark, N. J.).

Natural and artificial illumination. Natural illumination is derived from the sun and sky and reflected from the clouds, and consequently, varies greatly in intensity according to the astronomical and meteorological conditions. The intensity of average outdoor illumination in the temperate zone during the hours between sunrise and sunset may range from 500 to 5000 or more foot candles, depending on the time of day, the period of the year, and the weather.

The intensity of natural illumination of a room is governed not only by the intensity of the outdoor illumination, but also by the volume of light admitted through windows and other openings and reflected by surfaces within the room.

Artificial illumination is, as a rule, derived from a luminous source within the room and the intensity of illumination depends on the intensity of the light source and the brightness of the reflecting surfaces upon which the light falls.

Illumination requirements. The following table shows the minimum intensity of artificial illumination requirements, as measured by a foot-candle meter, for various rooms and activities.

	Minimum Requirement (*Foot candles*)
Squad room	5-7
Recreation room	
General	5-7
Reading tables or desks	7-10
Kitchen and mess halls	6-8
Libraries	
Book shelves	6-8
Reading tables	7-10
School rooms	
On desks	8-10
Typewriting	7-10
Gymnasium	5
Hallways	2-4
Storerooms	1-2
Laboratories	20
Operating room	75

Comparative value of natural and artificial illumination. The human eye possesses the faculty of adaptation within wide limits to gradually changing intensity of illumination. Beyond these limits, intense illumination, glare, or insufficient illumination causes discomfort, eyestrain or impairment of vision. Comparatively rapid changes in intensity of illumination within the range of visual adaptation will also cause glare effect or interfere with vision.

Natural illumination is generally more evenly distributed throughout a room than is the average artificial illumination, and the variations in intensity are not as abrupt, either in space or in time. Natural illumination is not, therefore, as

prone to cause eyestrain or impaired vision as artificial illumination and is preferable, when adequate, for lighting squad rooms and recreation rooms.

Light sources. The light for natural illumination of a room is derived primarily from the sky area visible through windows or doors, but the intensity of illumination within a room is determined largely by the brightness of the illuminated surfaces or, in other words, by the amount of light reflected by the walls, ceiling and floor.

The window area required to produce the desired intensity of available illumination will vary according to the proportion of the light reflected by the walls, ceiling and floor, the location of windows in relation to the space to be illuminated and the presence or absence of external objects, such as trees or buildings, which reduce the visible sky area. Given light colored walls of average reflecting power, that is, from 40 to 60 per cent, a uniform distribution of windows in the walls of the room, and no external obstruction of the visible sky area, the minimum window glass area for a room should be equal to from 12 to 20 per cent of the floor area.

The minimum window glass area required in the lighting of various buildings is shown in the following table. The window area given is in each instance for rooms having windows on both sides unless otherwise noted. With windows on one side, the minimum area applies only where the room is not more than 20 feet wide. The figures given represent the minimum, not the optimum area. The window area provided should be as much above the minimum as the type of construction and other conditions will permit.

	Minimum window glass area in per cent of floor area.
	Per cent
Squad rooms:	
Windows one side only	20
Windows on both sides	12
Recreation rooms:	
Libraries, schoolrooms, drafting rooms, etc.	20
Kitchens and mess halls	15
Gymnasiums	12

For example, a squad room 30 feet wide and 60 feet long would have a floor area of 1800 square feet and should, therefore, have a window glass area of not less than 216 square feet, if there are windows on both sides of the room. Given windows having an approximate glass area of 18 square feet, this room should have at least 12 windows.

The window glass area required for squad rooms may be calculated on a per capita, or bed space, basis. The minimum requirements are not less than seven square feet of window glass per bed space of 60 square feet of floor space, if there are windows on both sides of the room. In a room 20 feet wide with windows on one side only, the minimum requirement is 12 square feet of window area per bed space of 60 square feet of floor space.

Artificial illumination. Artificial illumination is derived from light sources within the room illuminated. These sources are of three kinds, direct, semi-indirect and total indirect.

Direct illumination. Direct illumination is derived from a light source which projects at least 50 per cent of the light directly towards the object illuminated without reflection from other surfaces. Direct illumination accentuates the shadows and tends to cause glare to a greater extent than either the semi-indirect or indirect method. This is particularly true where local light sources are employed, that is, where the source of light, such as a drop light, is placed close to the surface to be illuminated.

Direct illumination is economical in that but little light is absorbed before reaching the surface to be illuminated.

Semi-indirect illumination. In semi-indirect illumination, about 75 per cent of the light produced by the source is projected onto a reflecting surface, such as the ceiling or walls, by an inverted reflector. The light not reflected passes directly through the inverted reflector. The light which passes through the reflector together with that reflected from the ceiling and walls is diffused and produces a more uniform distribution of light throughout the illuminated space than results from direct illumination. The diffused light serves to reduce the intrinsic brilliancy, and therefore the glare, and to soften and reduce the extent of the shadows.

Some of the light is lost by absorption, the extent of such loss being inversely proportionate to the reflecting power of the walls and ceiling.

Total indirect illumination. In total indirect illumination, all of the light produced by the source is thrown against the reflecting surfaces of the ceiling and walls by opaque reflectors. This method produces the most uniform distribution and eliminates glare and heavy shadows. It has the disadvantage that much of the light is lost by absorption unless the reflecting power of the ceiling and wall surface is high.

Glare. Glare is brightness of such intensity as to produce discomfort or interference with vision. Glare results directly from the intrinsic brilliancy of a light source or indirectly from specular reflection. The production of glare, or the degree of glare produced by a given light source or reflecting surface, depends largely on the contrast between the brightness of such light source or reflecting surface and that of the surroundings or background. Thus, a bright light which when placed in a uniformly well illuminated space, or when seen in daylight, will produce no discomfort or interference with vision, may have a glare effect when seen in a dark space or as a single point in a field of view which is otherwise relatively poorly illuminated. This is illustrated by the difference in the effect produced by automobile headlights in daylight and in the dark.

The amount of glare is modified by the angular position of the light source when the visualized surface is in the center of the field of view. If the light source is so placed that the angle which the light rays make with the line of vision is 25 degrees or more, no glare is produced, regardless of the intrinsic brilliancy of the light source.

While the glare effect of direct rays from a light source, or a reflecting surface, varies with the intrinsic brilliancy and the contrast with the brightness of the surroundings, it may be assumed that intrinsic brilliancy in excess of five candle power per square inch will usually cause discomfort and interfere with vision.

Prevention of glare. Glare may be prevented by the diffusion of the light so that there is no specular reflection. It may be reduced by arranging lights so that the light sources are not in the field of view, by increasing the area of the illuminated sur-

faces or by decreasing the intrinsic brilliancy of the light sources or reflecting surfaces. Glare may be controlled and reduced to a minimum by the diffusion of light by means of total indirect or semi-indirect illumination. If direct illumination is employed, the glare effect is reduced by the use of shaded lamps or frosted bulbs and by increasing the elevation of the light source above the eye level. Generally, a lamp should be shaded when suspended at an elevation above the eye level which is less than one-quarter of the distance from the lamp to the surface to be illuminated.

Prevention of glare in various activities. All libraries, recreation rooms containing reading tables, school rooms, or offices should be lighted by semi-indirect or total indirect illumination. Direct illumination may be used in squad rooms, gymnasiums, storerooms, or hallways, without serious glare effect, provided the lamps are placed at sufficient elevation above the eye level or are properly shaded.

CHAPTER V.

CONTROL OF INTESTINAL DISEASES

The intestinal diseases (page 13) as a group are transmitted from person to person by food and water, the infective agents being disseminated in the excreta of cases or carriers. The causal organisms are introduced into water with the infected excreta, and into food through the medium of hands contaminated with infected material, by water, by contaminated dishes and utensils, by flies, or by direct contact with excreta. Occasionally, intestinal diseases may be transmitted by contact, that is, by the direct transference of infected excreta by the hands or by fomites to the mouth without the intervention of food or water as an intermediate agency. However, under average conditions, such contact is a relatively unimportant factor in the transmission of most of the intestinal infections among troops.

General importance and prevalence. Intestinal diseases are of great *potential* importance to a military force. However, measures are available by which the incidence of intestinal diseases can be greatly reduced below that which would and does occur in situations where the spread of these infections is inadequately controlled.

As sources of infection are constantly present in military organizations, and in the civilian populations with which the troops are in contact, any relaxation in measures for the control of intestinal infections will almost inevitably be followed by the occurrence among troops of some one of these diseases in epidemic form. The prevalence of intestinal diseases and their importance to a military force are, therefore, to a very considerable degree dependent on the extent to which suitable control measures are enforced. In this respect, intestinal dis-

eases differ markedly from such respiratory infections as influenza or common colds. In many instances, the latter cannot be completely controlled by any practical procedure, while uncontrollable epidemics of intestinal diseases seldom, if ever, occur in military forces under normal conditions.

While one attack of certain of the intestinal diseases, particularly typhoid and paratyphoid fevers, will usually confer permanent immunity, troops generally have a high group susceptibility to intestinal diseases.

The group of diarrheal diseases which are classified as common diarrhea are, from a military viewpoint, under ordinary conditions, the most important of the intestinal diseases largely because of their influence on the noneffective rate. This group includes those conditions diagnosed as enteritis, colitis, or diarrhea, which, in many instances, are probably actually mild dysenteries or food infections. These conditions tend to occur as small explosive epidemics and incapacitate a relatively large number of men before control measures can be made effective. On the other hand, typhoid and paratyphoid fevers are of relatively minor importance, but only because they can be controlled by available and practical control measures.

General control measures. The control of intestinal diseases is based on the control of environmental conditions with a view to preventing the transmission of the causal organisms by water and food. General measures for the control of intestinal diseases include water purification, food protection and control, waste disposal, and control of the house fly (Fig. No. 19). Each of these subjects is considered in detail in succeeding chapters.

Group quarantine of contacts is not, as a rule, effective or of value in the control of intestinal diseases. It may, however, be employed in the control of cholera. Cases of any intestinal disease may be isolated as individuals or in groups during the infectious stage of the disease. Carriers may be quarantined or their activities restricted in order to prevent the contamination of food or water or the transmission of infection by contact.

Food handlers are particularly important in the transmission of the etiological agents of many of the intestinal diseases, in that they have many opportunities to transfer the infective

organisms to the food or eating utensils of other persons (page 571). All food handlers should be required to cleanse their hands thoroughly before starting work in a kitchen or mess, and after each visit to a latrine. Preferably, they should disinfect their hands by washing them in a weak solution of cresol and drying them in the air without wiping.

Prophylactic immunization is employed as a routine measure in the control of typhoid fever, and may at times be utilized in the control of other intestinal diseases, particularly cholera, bacillary dysentery and paratyphoid fevers.

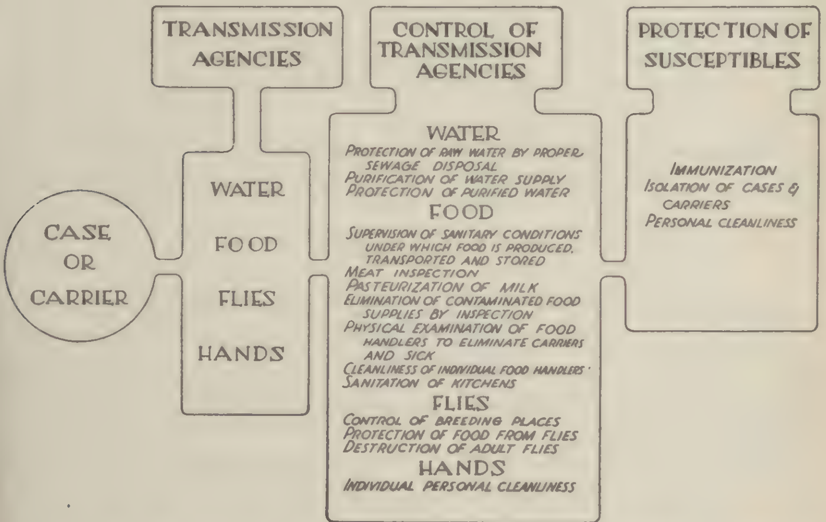


FIG. No. 19. General factors in the control of intestinal diseases.

Concurrent and terminal disinfection. Concurrent disinfection should be practiced in the care of patients having an intestinal disease, in order to prevent the transmission of the causal organisms by contact or through contamination of food or water which is to be consumed by others. It is essential that the feces and urine be thoroughly disinfected and properly disposed of. Any articles which might be soiled by excreta should be disinfected or burned.

Intestinal discharges may be disinfected by adding two per cent cresol solution or ten per cent formaldehyde and allowing them to stand for at least one hour. The quantity of

disinfectant used for this purpose should be equal to at least twice the volume of the material to be disinfected. Urine may be disinfected by the addition of sufficient cresol to make an approximate two per cent solution. Mercuric chloride in amounts sufficient to make a 1:1000 solution may also be used.

Patients should have separate dishes and eating utensils which should be disinfected by boiling after use. Any food which has been served to patients but not consumed should be destroyed or disposed of in such a manner that it will not convey the infection to others.

All sheets, pajamas, towels or similar articles used by the patient should be disinfected by boiling or by immersion in a two or three per cent cresol solution.

Medical officers, nurses and attendants should exercise care to prevent the transmission of infection by the hands or clothing.

Terminal disinfection should consist generally of thorough cleaning of the room or ward and disinfection of the bedding.

TYPHOID FEVER

Definition. Typhoid fever is an acute communicable disease caused by *Eberthella typhi* (*Bacillus typhosus*). It is manifested, clinically, by continued fever of a characteristic type, specific enteritis, splenic enlargement, a macular (rose-spot) eruption, and toxemia.

Incubation period. The incubation period of typhoid fever is usually from ten to fourteen days, but may vary from seven days to twenty-three days. The length of the incubation period is probably dependent to some extent on the size of the infecting dose of typhoid bacilli and the virulency of the organisms.

Susceptibility and immunity. Man is universally susceptible to typhoid fever. Apparently, neither sex nor race has any influence on susceptibility. The disease occurs most frequently during youth and early adult life, and is relatively uncommon during the later years of life.

One attack of typhoid fever confers permanent immunity in most instances, but second attacks occasionally occur.

Prevalence. Geographically, the distribution of typhoid fever is world wide. Climate, *per se*, does not affect the preva-

lence of typhoid fever, except as it modifies the habits and movements of man and influences the chances for the bacilli to survive outside the human body. There is, in many localities, a marked seasonal variation in prevalence which is probably, for the larger part, due to a corresponding variation in the exposure rate. Usually, in civilian communities, the incidence is greater during the months of July, August and September, and reaches the highest peak for the year in October, after which it gradually decreases and remains low during the winter and spring months. The increased incidence during the summer and early autumn is apparently due to the fact that during this part of the year more people frequent districts where measures for the control of typhoid fever are not enforced. Typhoid fever due to water-borne infection tends to occur in epidemic form during the colder months.

In the absence of immunization, either natural or artificial, the prevalence of typhoid fever in a community and the character of the epidemics are governed largely by the sanitary conditions under which the inhabitants live. In communities having a potable water supply and adequate supervision of food supplies, the incidence of typhoid fever is low and the disease tends to disappear. Under these conditions, typhoid fever prevails only as endemic or "residual" typhoid and occurs in the form of sporadic cases or limited epidemics. Residual typhoid is spread principally by carriers through the medium of food, contact and flies.

At the present time, typhoid fever is mainly a disease of rural communities and of towns and villages unprotected by adequate environmental sanitation. It occurs in epidemic form in the larger cities only when there is a break in the protecting barrier of water purification and food protection.

Prior to the introduction of proper sanitary protection and anti-typhoid vaccination, typhoid fever was a serious disease in military forces in both peace and war (Fig. No. 20). During peace, typhoid fever no longer occurs among the troops except as an occasional sporadic case. Massive infection is prevented by environmental sanitation and the endemic or residual incidence which would otherwise prevail is controlled by immunization. The incidence of imported cases, that is, cases among recruits who have been infected prior to enlistment, has been reduced by the decrease in the incidence of the disease in civilian communities. Also, the opportunities for troops to make contact with

TYPHOID FEVER. ADMISSIONS BY YEARS 1898-1935.
ENLISTED MEN IN UNITED STATES.
Rates per 1000 strength per annum.

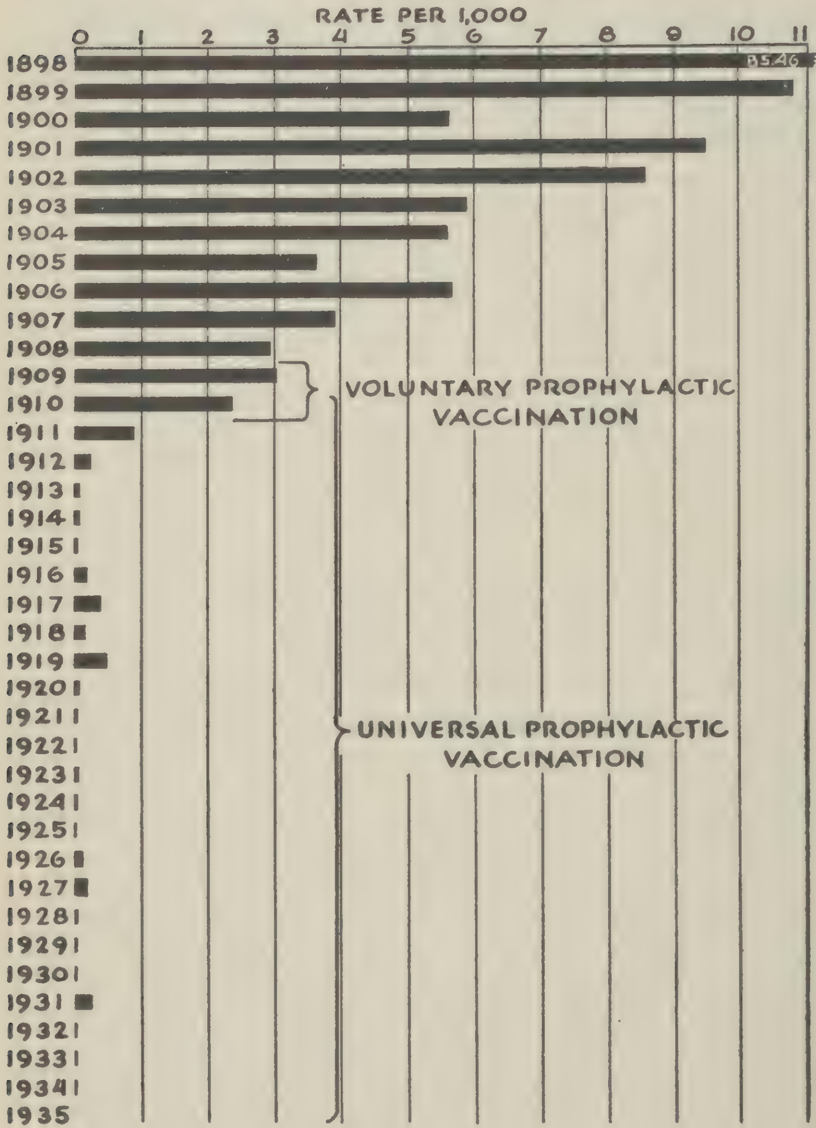


FIG. No. 20.

sources of infection outside of military stations and camps have been greatly reduced by the measures taken by civilian communities to control dissemination of the infection.

During the World War, there were 1529 admissions to hospital for typhoid fever among approximately 4,000,000 troops, or an annual rate of 0.37 per 1000 strength. Of this number 546 cases occurred in the United States and 885 among the troops in the American Expeditionary Force, giving an annual rate of 0.24 per 1000 strength for the troops in the United States, and 0.53 per 1000 for those in the American Expeditionary Force. In the larger proportion of the cases occurring in the United States, the infection was acquired prior to enlistment. The greater prevalence of typhoid fever in Europe was, in all probability, due to more numerous opportunities for exposure to massive or repeated doses of infection which eventually overcame, in certain individuals, the resistance that had been conferred by anti-typhoid vaccination (*infra*).

In 1933, there were seven cases of typhoid fever reported among 136,491 troops. Five of these cases had received the typhoid vaccine. Two had not been vaccinated, and one of these contracted the infection prior to enlistment. In 1934, eight cases of typhoid fever occurred among 134,716 troops. All had been immunized with typhoid vaccine. In 1935, there were four cases among 142,568 troops. All occurred in the Philippine Islands and all had been immunized. The number of troops given is the average daily strength, which, because of original enlistments to fill vacancies created by discharges, is considerably less than the number of troops exposed to risk of infection during the year.

The low prevalence of typhoid fever among American troops is due to the *constant and continuous application of control measures*. Typhoid fever is, at the present time, relatively unimportant, in so far as its influence on the noneffective rate and military operations is concerned, solely because of the effectiveness of the control which can be established and maintained. However, should control be relaxed or should the measures adopted prove inadequate, typhoid fever would undoubtedly again become a menace to the health of the troops and to the success of military activities.

Carriers. Carriers of typhoid bacilli are important sources of infection, especially in the spread of typhoid fever

by food and contact. The cases of typhoid fever due to infection transmitted by carriers is relatively larger at present than during the past, and it is probable that in the future an increasing proportion of cases will be due to carriers, as compared with other sources of infection.

Incubationary carriers, or mild or missed cases, no doubt serve as sources of infection, especially during an epidemic. Aside from incubationary carriers, the carriers of typhoid bacilli are classified as temporary, convalescent carriers and chronic carriers. The convalescent carrier is one who ceases to be a carrier within three months after recovery from an attack of typhoid fever. A chronic carrier continues to discharge typhoid bacilli subsequent to three months after recovery, and may remain a carrier for months or years, or for life. The incidence of the chronic carrier state is higher among females than among males.

Carriers, both chronic and temporary, are found who give no history of having had typhoid fever, and presumably have acquired the carrier state by contact or from having had a mild, undiagnosed attack of the disease. However, carriers who have not had the disease are rare and constitute only a small proportion of the known carriers.

The bacilli may be discharged in either the feces or the urine, but intestinal carriers are more common and also more dangerous than urinary carriers. The bacilli may be present in the feces or urine at all times, or they may be discharged intermittently and, in some instances, only at relatively long intervals. A single negative bacteriological examination of the feces and urine is not, therefore, conclusive evidence that the person examined is not a carrier. At times a positive result is obtained after several negative examinations.

The foci of infection in chronic intestinal carriers are ordinarily in the gall bladder or biliary ducts. In urinary carriers the primary focus of infection is usually in the pelvis of the kidney, but secondary foci may be located in the ureters or bladder.

A considerable number of typhoid fever patients continue to discharge typhoid bacilli for a limited period after recovery. It has been estimated that about 30 per cent are convalescent carriers for from two to four weeks after the disappearance of clinical symptoms. Gay estimates that from

four to five per cent of recovered cases remain chronic carriers.

The number of typhoid carriers in a given military force must, necessarily, vary with the previous experience of the troops with typhoid fever, but the ratio is probably less than one carrier per 1000 men. The incidence of typhoid fever in the general population has been and is gradually decreasing, and, obviously, the incidence of chronic carriers will decrease as the incidence of the disease decreases.

Usually, the carrier who happens to become a source of infection is a food handler or is engaged in activities which permit him to contaminate the food of others. Under these circumstances, the carrier frequently is the cause of limited outbreaks of typhoid fever. Occasionally, a carrier who is a milk handler is the primary source of infection for an extensive epidemic of milk-borne typhoid fever. At other times, he may transmit the infection by contact and thus be responsible for sporadic cases. However, there must be many carriers who never transmit the infection to others, or do so but rarely, because their activities are such that they do not have the opportunity to contaminate food or water, or to transfer the organisms by contact.

Transmission. In the transmission of typhoid fever, the infection is always of human origin. The causal organisms are eliminated from the body in the feces and urine and are transferred from person to person in water or food, or by contact.

The infection is communicable by a patient from the time the prodromal symptoms appear, throughout the course of the disease, and during convalescence until the feces and urine no longer contain typhoid bacilli.

Typhoid bacilli enter water in infected human excreta. They do not multiply, nor do they survive for any considerable period of time in water. In ordinary surface water, it is probable that most of the organisms die in less than a week. Consequently, water serves merely as an agent for the mechanical transfer of the causal organisms from person to person and, in order to create and maintain epidemic conditions, the water supply must be constantly and relatively heavily contaminated with infected excreta.

The foods most commonly incriminated in the transmission of typhoid fever are milk and milk products, oysters, and leafy vegetables that are eaten raw. Milk may be infected with typhoid bacilli by a milk handler who is a carrier or who has the disease in a mild form. The local water supply may also infect the milk at the dairy or at some time during the handling process. As milk affords a good medium for the growth of typhoid bacilli, the introduction of only a few organisms at the dairy may result in the entire supply being heavily infected by the time it reaches the consumers. Milk products, especially ice cream, are also efficient agents for the transmission of typhoid bacilli.

Oysters, and occasionally other shellfish, may become infected with typhoid bacilli when grown or stored in water contaminated with human excreta (Chapter X).

Vegetables which have been grown in soil fertilized with human excreta may become contaminated with typhoid bacilli and when eaten raw serve to transmit the infection to the consumer.

Articles of food which require considerable handling during preparation and which may be held for some time prior to consumption, particularly such dishes as salads, frequently serve as agents for the transmission of typhoid fever. The food is infected during preparation in the kitchen and the source of infection is the food handler who is a carrier or has the disease in a mild form or in an early stage.

House flies may carry typhoid bacilli from excreta in latrines to the food in kitchens and messes. Flies are especially dangerous in the contamination of food which has been prepared for serving.

Soil contaminated with infected excreta may carry typhoid bacilli into food or water. It is probable that the bacilli will survive for a considerable period of time in heavily polluted soil.

Sporadic cases or limited epidemics of typhoid fever may be caused by the transmission of the infection by contact or close personal association between susceptibles and persons who are sources of infection. Articles contaminated with infected excreta may serve as the intermediate agents for hand to mouth transmission of the causal organisms. The hands

may be contaminated by soiled clothing, bedding or latrine seats. Eating utensils may also carry the infection.

Control measures. The control of typhoid fever is based first, on preventing the transmission of massive or continuous infection by water, food and contact, that is, by water purification, food control and waste disposal, and second, on immunization by prophylactic vaccination. Environmental sanitation cannot, from a practical point of view, be carried out to a degree which will entirely prevent the transmission of the causal organisms of typhoid fever under all military conditions. This is especially true with troops in the field and in combat. However, practical control measures are available which will, except under the most abnormal conditions, prevent the *continuous* transmission of infection or the transmission of massive doses of the organisms.

Immunization by prophylactic vaccination will, in the vast majority of instances, afford protection against the incidental and moderate exposure to infection to which the troops may be subjected in the presence of good environmental sanitation. Without immunization, such exposures would, undoubtedly, cause many cases of typhoid fever. Immunization is not, therefore, a substitute for sanitation, nor can sanitation alone be depended upon to afford full protection from the disease.

Prophylactic vaccination. The typhoid vaccine used in the army at the present time is manufactured at the Army Medical School and consists of one thousand million killed typhoid bacilli in one cubic centimeter of salt solution. A triple vaccine containing typhoid, paratyphoid A and paratyphoid B organisms was used during the World War, in the immunization of all troops. Subsequent to the World War, because of the low incidence of paratyphoid B fever, and also because of the reactions produced by the paratyphoid B fraction, the paratyphoid B organisms were eliminated from the vaccine. Later, the paratyphoid A fraction was likewise eliminated from vaccine, mainly because there is but little danger during peace of troops being exposed to infection with paratyphoid A organisms. Should the troops be again exposed to paratyphoid fever, during war or under other conditions, the vaccine used would again include the paratyphoid organisms.

The typhoid vaccine is administered in three doses at intervals of approximately a week. Usually, the first dose con-

sists of one-half c.c. of the vaccine and the second and third doses of one c.c. each. If necessary, the time between injections may be reduced to three days. The dosage for children is proportionate to the body weight.

The vaccine must be injected *subcutaneously.* Intramuscular injections are followed by rapid absorption, with the consequent danger of severe general reactions. The injection is usually made at about the insertion of the left deltoid muscle.

A local reaction practically always follows the injection of typhoid vaccine and is usually the most marked after the second injection. As a rule, it consists of a red, tender area from one to several inches in diameter, but which may extend for some distance down the arm and, in some instances, may be accompanied by involvement of the axillary glands. The local reaction subsides rapidly and requires no treatment.

In the great majority of instances, one or more of the doses of typhoid vaccine produces a general reaction which is usually slight and transitory but may be manifested by malaise, fever and muscular pains. Occasionally, the more severe reactions may be accompanied by nausea, diarrhea and albuminuria. While a general reaction may follow any one of the three injections, it occurs most commonly after the second dose.

As a rule, the symptoms of a general reaction subside in less than twenty-four hours. Moderately severe reactions occur in about ten per cent of vaccinated individuals, but hospitalization is required for only a small proportion of the cases, usually not more than one per cent. All troops should, however, be excused from duty for a period of twenty-four hours after vaccination.

Severe or bizarre reactions occasionally occur but are very rare. Symptoms simulating those of meningitis or appendicitis have been noted. No deaths were reported as due to typhoid vaccination during the World War.

The immunity produced by typhoid vaccination is relative, not absolute, and varies in degree and duration in different individuals. As a rule, some degree of immunity is undoubtedly retained indefinitely and it is generally believed that one course of the vaccine will, in most instances, afford protection against moderate doses of infection for as long as three years. In the army, one course of vaccine is given at the time of entry into the service and a second course three

years later. Thereafter, re-vaccinations are made only when indicated by exposure, or threatened exposure, to infection.

At any time when there is danger that troops will be exposed to typhoid fever, all those who have not been vaccinated within the last twelve months should be re-vaccinated as a routine control procedure. In time of war, all troops should be vaccinated or re-vaccinated within twelve months prior to entering a theater of operations and annually thereafter as long as they remain under combat conditions.

All children over three years of age should be vaccinated, two or three courses being given at intervals of three years. If there is danger of infection, all children over six months of age should be vaccinated.

Carrier control. The detection of a typhoid carrier is usually based primarily on epidemiological studies, the results of which indicate that someone within a small group of persons is responsible for the dissemination of the infection causing an outbreak of typhoid fever. The epidemiological findings are confirmed or disproved by the bacteriological examination of the feces and urine of the suspected individuals. The low incidence of the carrier state and the fact that the bacilli may be discharged intermittently renders it extremely difficult and, as a rule, impracticable, to isolate by surveys and bacteriological examinations of the feces and urine all the carriers present in a military organization.

A thorough search for carriers should be made whenever typhoid fever occurs as a limited epidemic or as sporadic cases. Usually, under these conditions, the source of the infection is a carrier, or a mild case of typhoid fever, who is a member of the group of individuals among whom the cases occur. Also, where the primary source is a carrier, the causal organisms are usually transmitted by food or contact. Occasionally, in a vaccinated population, water-borne infection may result in the appearance of sporadic cases or small epidemics, but, as a rule, the cases are scattered and cannot be attributed, on epidemiological grounds, to transmission by food or contact.

While the typhoid carrier is not necessarily dangerous to others if his activities are restricted so that he cannot transmit the organisms to others by food or contact, nevertheless, in the military service he should be isolated for observation and

treatment. If the carrier state persists for longer than three months, he should be discharged from the service. The proper civilian health authorities should always be notified when a typhoid carrier is discharged.

The treatment of chronic typhoid carriers is unsatisfactory and a permanent cure is seldom attained, except by surgical procedures. If the focus of infection is in the gall bladder, cholecystectomy may effect a cure of the carrier state, but if the bile ducts are involved, excision of the gall bladder does not cure the carrier condition. If the focus of infection is one of the kidneys, nephrectomy will accomplish a cure. However, in view of the fact that the typhoid carrier can so arrange his activities that there is little danger that he will transmit the infection to others, surgical intervention as a means of curing the carrier condition is seldom justified.

Many drugs and chemical compounds, including neosalvarsan and other arsenic preparations, urotropin, methylene blue, and iodine, have been administered to typhoid carriers in efforts to cure the carrier state, but none has yielded satisfactory results.

Carriers of typhoid bacilli, including convalescents, should not be released from control until a series of examinations of the feces or urine show that the organisms are no longer being discharged. At least four negative examinations at intervals of not less than twenty-four hours should be required.

Concurrent and terminal disinfection. Thorough concurrent and terminal disinfection should be practiced in the care of typhoid fever patients. All excreta should be thoroughly disinfected before disposal. All articles contaminated with excreta should be disinfected or burned (page 155). Terminal disinfection should, where practicable, include steam disinfection of mattresses and blankets.

PARATYPHOID FEVERS

Definition. The paratyphoid fevers are acute infectious diseases which, clinically, closely resemble typhoid fever, except that, in certain forms, gastro-enteritis may predominate. They are, however, distinct disease entities and immunity to paratyphoid fever is not conferred by an attack of typhoid fever, nor *vice versa.*

Paratyphoid A fever usually differs from typhoid fever only in that it runs a milder course. However, severe and even fatal cases may occur. Typical paratyphoid B fever also closely resembles typhoid fever, but is frequently characterized by acute gastro-intestinal symptoms similar to those occurring in food infections, with which it may be confused during its earlier stages.

In many instances, paratyphoid fevers cannot be clinically differentiated from typhoid fever and the diagnosis is dependent on the agglutinating properties and cultural characteristics of the causal organisms.

Etiology. Organisms of the *Salmonella* group are the etiological agents of the paratyphoid fevers. Paratyphoid A fever is caused by *Salmonella paratyphi* (*Bacillus paratyphosus A*) and paratyphoid B fever by *Salmonella schottmuelleri* (*Bacillus paratyphosus B*). *Salmonella hirschfeldii* is the causative agent of a disease known as paratyphoid C or paratyphoid N fever occurring in Europe. These organisms are closely related to *S. aertrycke*, *S. enteritidis* and *S. suipestifer* which are frequently the cause of food infections.

Incubation period. The incubation period of paratyphoid fever is from four to fifteen days, usually from seven to ten days.

Susceptibility and immunity. The susceptibility of troops to paratyphoid fever is considered to be about the same as their susceptibility to typhoid fever (page 156). One attack of the disease usually confers permanent immunity, but second attacks occasionally occur. An attack of paratyphoid A fever does not immunize against paratyphoid B fever nor does an attack of the latter disease protect against paratyphoid A fever.

Prevalence and importance. The prevalence of paratyphoid fever is much less than that of typhoid fever. Paratyphoid fever tends to occur as limited epidemics or as sporadic cases, and extensive outbreaks are rare. It may be, and frequently is, present with typhoid fever in endemic or epidemic form, but the proportionate incidence of paratyphoid fever varies greatly. In the United States, paratyphoid B fever is somewhat more prevalent than typical paratyphoid A fever. It is probable that a considerable number of cases of

paratyphoid fever are actually diagnosed and reported as one of the common diarrheal diseases (page 181).

During the World War, 134 cases of paratyphoid A and 95 cases of paratyphoid B fever were reported as occurring among approximately 4,000,000 troops, as compared with 1529 admissions to hospital for typhoid fever.

Transmission. Generally, the paratyphoid bacilli are transmitted in the same manner and by the same agencies as the typhoid bacilli.

Paratyphoid fevers are communicable from the time that prodromal symptoms appear throughout the course of the disease and the period of convalescence until the causal organisms are no longer discharged in the feces or urine.

Carriers probably play an important role in the dissemination of the paratyphoid bacilli. They are especially dangerous as food handlers and should be controlled in the same manner as typhoid carriers.

Control measures. The same measures are employed for the control of paratyphoid fever as are used to control typhoid fever (page 163). Vaccination with paratyphoid vaccine confers immunity to paratyphoid fevers to about the same degree as typhoid vaccine immunizes against typhoid fever (page 163).

BACILLARY DYSENTERY
(*Epidemic dysentery*)

Definition. Bacillary dysentery is an infectious disease which is characterized, clinically, by the frequent passage of stools containing blood and mucus, and by abdominal pain, tenesmus and toxemia.

Etiology. Bacillary dysentery is caused by *Shigella dysenteriae* (*Bacillus dysenteriae*), of which there are a number of types or varieties. The most important of these are the Shiga-Kruse variety, the Sonne variety and the Flexner group (*Shigella paradysenteriae*). The latter group includes a number of strains. In the United States, the Flexner group of dysentery bacilli are more frequently the etiological agents of bacillary dysentery than any of the other varieties of the dysentery bacillus. As a rule, the Shiga variety causes a more severe form of

dysentery than other types of the organism, but severe cases may be caused by any of the different varieties.

Incubation period. The incubation period of bacillary dysentery is usually from two to three days. It is variable and may be less than two days or possibly, in rare instances, as long as seven days.

Susceptibility and immunity. While persons of all ages are susceptible to bacillary dysentery, the disease occurs most frequently among young adults and children under two years of age. It is probable that one attack of bacillary dysentery confers some immunity to subsequent infections, but this question has not been definitely determined. Repeated attacks do occur but, in some instances at least, they may represent exacerbations of a chronic infection. Fatigue and other depressing factors appear to increase the susceptibility to the disease, as exemplified by the increased incidence under combat conditions.

Prevalence. Bacillary dysentery tends to occur in epidemic form, but may be endemic or sporadic. It is pre-eminently a disease of faulty sanitary environment and is particularly prone to appear as an epidemic during periods of intensive military activity, when measures for the protection of the food and purification of water cannot be, or are not, enforced. While the distribution of bacillary dysentery is world-wide, it is more prevalent in tropical and sub-tropical regions. It also tends to be more prevalent during the warmer months of the year.

Bacillary dysentery is an important disease among troops, chiefly because it is most apt to prevail during periods of military activity or combat when the difficulties connected with disease control and the care of the sick are the greatest. It is also undoubtedly responsible for much of the so-called common diarrhea and the inefficiency and noneffectiveness resulting from that condition.

Transmission. Generally, bacillary dysentery is spread in the same manner as other intestinal diseases, that is, from cases and carriers, by infected water and food, and by contact. The infection is communicable by the patient throughout the course of the disease and convalescence until the causal organisms are no longer contained in the feces. Mild and missed cases are important sources of infection, as they are

frequently regarded as common diarrhea and are not properly controlled (page 181). In most instances, the infection is transmitted by food or by indirect contact and, to a less extent, by water. Food which has been contaminated by food handlers is an important agent in the transmission of bacillary dysentery.

The bacilli are discharged in the feces but, as they do not invade the blood stream, they are not present in the urine. The frequent passage of fecal material containing enormous numbers of the dysentery bacilli, together with the tenacious mucoid character of the stools, facilitates the transfer of the organisms through indirect contact by means of the hands. Latrine seats, clothing and anything which is touched by the patient or by his attendants is apt to become contaminated with the infected material and serve to transfer the causal organisms to others. Under suitable conditions, house flies may be important factors in the spread of the infection.

The dysentery bacillus is resistant to cold and will live for a considerable period of time in moist material. It will remain viable on clothing and other articles for as long as a week to ten days.

Carriers. Convalescence from bacillary dysentery may be prolonged with frequent exacerbations and remissions, and chronic dysentery is not uncommon. The convalescent and chronic cases disseminate the infection in the same manner as convalescent and chronic carriers (page 16). While healthy carriers may exist, it is believed that, in most instances, the supposed carriers of dysentery organisms are, in reality, convalescent or chronic cases, and that the discharge of organisms in the feces is symptomatic of a relapse.

It is generally estimated that about three per cent of the known cases of bacillary dysentery become carriers to the extent that they continue to excrete the organisms after apparent recovery from the disease. Ordinarily, the carrier state is self limiting, but may, in some instances, be prolonged indefinitely.

Carriers, including chronic cases, usually excrete the organisms intermittently. The bacilli may be absent from stools for long periods of time, only to appear at intervals, sometimes in large numbers. Convalescent and chronic cases and carriers are particularly dangerous sources of infection when engaged as food handlers.

Control measures. The general measures for the control of bacillary dysentery are the same as those applicable in the control of any intestinal disease (page 154).

In the presence of bacillary dysentery, special attention should be given to the protection of the food of the troops. All food handlers should be examined for evidence of the disease and no man should be retained on duty as a food handler who shows any indication of diarrhea or intestinal infection, even though dysentery bacilli cannot be found in the feces. All troops should be warned against eating food obtained from sources other than army messes or exchanges, and suitable orders forbidding such acts should be issued. Orders providing for washing of the hands after visiting a latrine should be issued for the entire command and strictly enforced (page 155).

It is necessary in the control of bacillary dysentery—more perhaps than in the control of any other intestinal disease—to secure the cooperation of the individual members of a command and especially the cooperation of the officer and noncommissioned officer personnel. To this end, whenever bacillary dysentery occurs in a command, or there is danger of an epidemic, the troops should be instructed in the nature of the disease and the means by which it is spread. Special emphasis should be given to the value of personal hygiene and cleanliness in preventing the transmission of the infection.

No man who is known to have had or who gives a definite history of having had bacillary dysentery should be assigned to duty as a food handler, even though the feces are negative for the dysentery bacilli.

The early and prompt reporting for treatment of all cases of diarrhea is especially important in order to control the spread of the infection by mild and missed cases of dysentery. All men complaining of diarrhea should be reported at once to the surgeon by their officers or noncommissioned officers.

Vaccines have not been used with any considerable degree of success in the control of bacillary dysentery in military forces. The injection of dysentery vaccines is, as a rule, followed by a severe reaction, especially where the Shiga bacillus is used. The sensitized vaccines are less toxic than the ordinary saline vaccine. The immunity conferred by dys-

entery vaccines apparently does not afford protection from the disease for longer than two or three months.

Control of carriers. The control of carriers, including the control of chronic and convalescent cases, is an important factor in controlling the spread of bacillary dysentery. No case of bacillary dysentery should be discharged from the hospital until bacteriological examination of the feces shows that the bacilli are no longer being eliminated. Owing to the tendency for the organisms to be discharged intermittently, a series of such examinations should be made, the number of which will depend somewhat on the nature of the case in question, especially the chronicity. In any event, at least four negative examinations, made at intervals of not less than twenty-four hours, should be obtained before a patient is returned to duty. Where time and facilities permit, no convalescent patient should be discharged from the hospital until his stools have been negative for a period of two weeks, as determined by at least four bacteriological examinations.

Concurrent and terminal disinfection. Owing to the facility with which the causal organisms of bacillary dysentery are transmitted by the hands and inanimate articles, thorough concurrent disinfection is essential in preventing the spread of the infection in hospitals (page 155). Special attention should be devoted to disinfection of the hands of those who care for the patient and of all articles, such as bedpans, urinals, bed linen, or dishes, which come into contact with, or are handled by, the patient.

Terminal disinfection should consist of thorough cleaning and disinfection of all bed linen and blankets used by the patient. Pillows and mattresses should be disinfected in a steam disinfector or, if a steam disinfector is not available, by thorough sunning or airing. The bed and the floor around the bed should be disinfected by scrubbing with an antiseptic solution.

AMEBIC DYSENTERY

(Amebiasis, Endamebic dysentery)

Definition. Amebic dysentery is an infectious disease which is manifested clinically in its acute stages by the frequent passage of stools containing blood and mucus, and by

abdominal pain and tenesmus. The onset is usually insidious, and the course of the disease is characterized by a marked tendency to become chronic with occasional exacerbations and relapses of varying severity. In many instances, the disease is manifested only by mild symptoms consisting of gastrointestinal disturbances, diarrhea, loss of weight, and weakness.

Frequently, difficulty is encountered in differentiating amebic dysentery from other abdominal conditions. Acute amebic dysentery may simulate acute appendicitis, and subacute or chronic cases may present the symptomatology of other infections.

Etiology. Amebic dysentery is caused by the invasion of the tissues of the large intestine by the protozoon, *Endameba histolytica*, with the production of an ulcerative colitis and dysenteric symptoms. Extension of the infection may occur, the most common manifestation of which is abscess formation in the liver. More rarely the brain may be involved.

The life cycle of *E. histolytica* includes three distinct forms which constitute the vegetative, the pre-cystic, and the cystic stages. The vegetative forms are the motile trophozoites which invade and live in the tissues of the intestinal wall, where they produce ulcers with the consequent symptoms of amebic dysentery. They multiply by simple fission. When discharged from the body, the vegetative forms degenerate rapidly and will live only for a very short time. If ingested, they are probably destroyed by the gastric secretions and are not, therefore, infective.

Four nucleate cysts develop from the vegetative forms after passage through a pre-cystic stage. The cystic form is the infective agent of amebic dysentery, and encystment occurs naturally only in the intestine. The cysts are discharged in the feces and excystation does not occur in the intestine of the original host. The vegetative forms which are discharged in the feces do not develop into cysts. The cysts do not reproduce outside the intestine, but are able to survive in an adverse environment outside the body for a sufficient period of time to permit transfer from one host to another. When ingested, they pass unchanged through the stomach and small intestine and develop into the vegetative forms in the large intestine. Each cyst gives rise eventually to from four to eight vegetative forms which are liberated in the upper part of the large intestine.

In many instances, infection with the cysts of *E. histolytica* produces primarily a carrier state without the development of demonstrable symptoms. Carriers discharge the cysts in their feces intermittently over long periods of time. However, many of the carriers present obscure symptoms from time to time, and a considerable proportion eventually develop frank symptoms of amebic dysentery.

Incubation period. The incubation period of amebic dysentery is extremely variable and is difficult to determine. In experimental infections, where men were fed material containing the encysted forms, parasitization occurred in about nine days, and dysenteric symptoms developed in from twenty to ninety-five days after the ingestion of the cysts. Where the disease prevails in epidemic form, the onset occurs, in the majority of the cases, in the second week, usually 10 to 14 days after infection. In the Chicago epidemic (*infra*), the incubation period varied from about ten days to several months.

Susceptibility and immunity. Susceptibility to amebic dysentery is universal and is uninfluenced by race, sex or age. Excessive fatigue or exhaustion, exposure to inclement weather, and lack of proper food tend to lower the resistance to infection. In the vast majority of instances, the development of symptoms occurs only when the resistance of the infected individual is decreased. It is generally thought that an attack of amebiasis confers no immunity to future infections. It may be that some immunity is acquired against infection with an homologous strain of the organism.

Prevalence and importance. Amebic dysentery usually occurs in endemic form and sporadic cases are relatively common. It may, however, occur with epidemic prevalence where troops are subjected to infection from a common source, such as a contaminated water supply.

Amebic dysentery is primarily a disease of the tropical and sub-tropical regions of the world, but is also widespread in the temperate zones. It is most prevalent during the warm seasons of the year.

Amebic dysentery is important in a military force, largely because of its chronicity and incapacitating effect on the individual. It occurs most frequently among troops where primitive environmental conditions favor the transfer of infected excreta by contact and food, and arduous military ac-

tivities serve to lower their resistance to infection. *E. histolytica* is, no doubt, frequently the causative agent of so-called common diarrhea (page 181).

There were 926 cases of amebic dysentery reported as occurring among American troops during the World War. The diagnosis was based on the presence of *E. histolytica* in the stools, together with symptoms of intestinal infection. It is, however, probable that in a number of these cases the individuals concerned were carriers of *E. histolytica*, and the symptoms presented were due to infection with organisms other than *E. histolytica*. On the other hand, it is also probable that a certain number of the cases reported as common diarrhea were actually amebic dysentery.

Transmission. The cysts of *Endameba histolytica* are transferred from one person to another in contaminated food and water and by the hands. The sources of infection are healthy carriers and convalescent or chronic cases of the disease.

Amebic dysentery is communicable by the patient only when cysts are being discharged in the feces. The organisms discharged in the stools during an acute attack of amebic dysentery are chiefly the vegetative forms. As the symptoms subside, the cystic forms develop and appear in the feces in large numbers during convalescence. If the disease becomes chronic, the cysts continue to be discharged intermittently as long as the infection remains.

Healthy carriers constitute the principal source of infection. It is estimated that from five to ten per cent of the general population of the United States are carriers of *E. histolytica* and it can be assumed that the carrier incidence in a military organization is approximately the same as in the general population.

The cysts of *E. histolytica* will survive in water for a number of days, probably for several weeks. They will also remain viable for a considerable period of time in moist feces, or in or on moist foods. Moist green vegetables which have been grown in soil fertilized with human excreta may be contaminated with the cysts of *E. histolytica*. The cysts are also ingested by the house fly and excreted unchanged and viable for as long as one or two days after ingestion. Drying will destroy the cysts within a few minutes and moisture is therefore essential for their continued existence outside the human intestine.

Under ordinary conditions, food is a most dangerous agent for the transmission of the cysts of *E. histolytica.* However, during campaigns water may constitute the most common transmitting agent. For example, in the Chicago epidemic of amebic dysentery in 1933, during which there were more than 1000 cases, the infection was transmitted by water. In this epidemic, the cases occurred among persons living in certain hotels, and upon investigation it was found that the drinking water had been contaminated by sewage entering through cross connections and defective plumbing in the hotels.

Food may be contaminated by food handlers who are carriers of *E. histolytica,* or who have the disease in a chronic form. A contaminated water supply may also serve to transfer the cysts to the food. Food may also be contaminated by cysts contained in the excreta of the house fly, or carried on the surface of the body or appendages of the fly.

Control measures. The general measures for the control of intestinal diseases are applicable in the control of amebic dysentery (page 154).

Since the work of Wenyon and O'Conner in 1917 it has been thought that chlorine, in the amounts which could be used to disinfect water, would not destroy the cysts of *E. histolytica.* Recently, the results of an experimental study made by Captain Wm. S. Stone, M.C., U.S. Army, indicate that, under laboratory conditions, chlorine in quantities which will kill *B. coli* in water will also destroy the cysts of *E. histolytica.* However, it has not been proven that chlorination of water supplies in the field will destroy the cysts of *E. histolytica,* and chlorination cannot, as yet, be relied upon to protect against water-borne infection. Filtration of water will remove the cysts of *E. histolytica* (page 242). In the presence of amebic dysentery, where the infection is or might be transmitted by water, all unfiltered water used by troops should be boiled.

In localities where amebic dysentery is endemic, no raw vegetables should be served to the troops. Leafy vegetables, particularly lettuce, are especially dangerous.

In the physical examination of food handlers, particular attention should be devoted to the detection of carriers of amebic dysentery. If a history of attacks of diarrhea is obtained, the stools should be examined for the cysts of *E. histolytica* (Chapter XII). Further, whenever practicable, the stools of every food

handler, or prospective food handler, should be examined and no man found to be a carrier of *E. histolytica* should be assigned to duties requiring him to handle food to be consumed by others.

In communities where amebic dysentery is present among the civilian population, the consumption by troops of food obtained from civilian eating places should be restricted by orders.

Fly control measures are important in controlling the spread of amebic dysentery. Where amebic dysentery is present, particular attention should be given to the protection of food from contact with flies.

Among troops, avoidance of exhaustion and undue exposure to inclement weather are important factors in the control of amebic dysentery. Likewise suitable food is an important factor in maintaining the resistance of the individual to infection.

The large number of carriers renders their detection a difficult matter. Where cases of amebic dysentery occur among troops, every effort should be made to detect carriers that might be sources of the infection. All carriers that are found should be treated with a view to the cure of the carrier state. A number of compounds have been used in the treatment of carriers. Among those which have given generally satisfactory results are carbarsone, chiniofon, and acetarsone.

Concurrent and terminal disinfection. The usual concurrent and terminal disinfection measures should be practiced in the care of amebic dysentery patients (page 155). A two to five per cent solution of cresol is the most effective disinfectant for the destruction of the cysts.

CHOLERA
(*Asiatic cholera*)

Definition. Cholera is an acute infectious disease which is characterized by a profuse, relatively painless diarrhea and vomiting, serous, rice-water like stools, muscular cramps, suppression of the urine, dehydration of the tissues and rapid collapse.

Etiology. Cholera is caused by *Vibrio cholera* (*Spirillum cholerae asiaticae, Spirillum cholerae*, the comma bacillus). There are many vibrios to be found in nature which are morpho-

logically, culturally, and in their staining reactions similar to the true cholera vibrio, from which they can be differentiated only by agglutination tests with a specific serum, or by Pfeiffer's phenomenon. The cholera vibrios produce cholera only in man and will not produce the clinical syndrome of cholera in any of the lower animals. So far as is known, the cholera organisms are propagated only in man and are carried by none of the lower animals.

Cholera vibrios are readily destroyed by all the ordinary disinfectants. They are killed when subjected to a temperature of 132°F. for 30 minutes. Drying kills them in a few minutes.

The cholera vibrios will live in some waters for weeks or months and may even multiply, while in others they disappear in a short time. They are not killed by freezing. They will live for several days in or on non-acid foods, and will survive in milk until the milk becomes acid. They will live for relatively long periods in fecal material.

Incubation period. The incubation period of cholera is usually about three days, but it may vary from a few hours to as long as five or six days.

Susceptibility and immunity. All ages, races and both sexes are equally susceptible to cholera. The ingestion of the vibrios does not, however, cause the disease in all instances. Many of the organisms are killed by the acid gastric secretion, and the vibrios may pass through the normal intestinal canal without producing infection. Gastro-intestinal disturbances, fatigue, worry or fear enhance susceptibility and predispose to infection. An attack of cholera confers an immunity which apparently is fairly permanent. Second attacks occur but they are quite rare.

Prevalence and importance. Cholera tends to occur in the form of widespread epidemics. While, at the present time, cholera prevails only in tropical and sub-tropical countries, its spread is governed by environmental conditions, rather than by climate or seasonal influences. Cholera occurs in the Philippine Islands and is endemic in India and Asia generally. Because of the control measures employed, it rarely occurs among American troops in the Philippine Islands, but is, nevertheless, a potential menace to troops serving in the Islands.

Transmission. In the transmission of cholera, the primary source of infection is either the human case or carrier, and the disease is spread by water, food and contact. The organisms are disseminated in the discharges from the intestines and also in the vomited material. Mild cases and carriers are the most important sources of infection.

The period of communicability extends from the appearance of symptoms until the organisms are no longer present in the feces. Carriers of the cholera vibrios are numerous in the presence of epidemic conditions. Convalescent patients usually cease to be carriers in from four or five days to two weeks after the cessation of symptoms, but a temporary carrier state may persist for a month or longer. Chronic carriers are relatively rare. In districts where epidemics of cholera occur from time to time, as for example in the Philippine Islands, chronic carriers are present in the population at all times and probably serve as reservoirs of infection during interepidemic periods. Carriers are commonly found who have not had cholera, but these healthy carriers frequently develop the disease when some condition intervenes to lower their resistance.

House flies transmit cholera vibrios in the same manner as they transmit the causal agents of other intestinal diseases. Vegetables may be contaminated with cholera vibrios by being washed in contaminated water, or by the hands of carriers or those having the disease in a mild form, or by contact with excreta.

Control measures. The control of cholera is largely a question of water purification and protection of food, together with the control of cases and carriers, and vaccination. The proper disposal of excreta and the control of the house fly are essential measures of control (Chapters XIII and XVIII). In the presence of an epidemic of cholera, the detection of mild cases and carriers is an important factor in obtaining control of the situation.

All cases and carriers should be isolated until the carrier state has disappeared. Where a case of cholera occurs in a military organization, the close contacts and associates of the case may be placed in group quarantine until they can be examined for the presence of cholera vibrios in their stools

and until the cases or carriers which are found are removed from the group and isolated.

Cholera vaccines are of value and are administered in the same manner as the typhoid vaccine. The immunity produced is generally considered to afford protection against moderate doses of the vibrios for about six months. Troops which have been exposed to cholera, or are operating in a locality where cholera is endemic or epidemic, should be vaccinated. Vaccination of all troops is not necessary where good sanitary conditions can be maintained.

In the prevention or control of cholera in a military organization, the individual cooperation of each member should be obtained by suitable instructions and orders. Each man should be impressed with the danger of drinking water which has not been either chlorinated or boiled and of eating uncooked food. The troops should not be allowed to consume food or drink obtained from unauthorized sources. The consumption of food or drink obtained by the individual soldier from native sources should, ordinarily, be strictly prohibited. Special attention should be given to personal hygiene, particularly the cleanliness of the hands.

In the presence of cholera, a special effort should be made to maintain or improve the general health of the troops. All unnecessary exposure to heat, inclement weather or excessive fatigue should be avoided.

If cholera has occurred in a command or is present among the civilians of adjacent localities, every person having diarrhea or mild gastro-intestinal disturbance should be regarded as a cholera suspect until proven otherwise.

Concurrent and terminal disinfection. In the care of the cholera patient, all excreta should be thoroughly disinfected. Articles which are touched by or come in contact with the patient should be destroyed or disinfected. Special attention should be given to the disinfection of the hands of the attendants. Otherwise, the measures described on page 155 should be enforced.

COMMON DIARRHEAS
(*Enterocolitis, Enteritis, Colitis, Diarrhea*)

Definition. The common diarrheas are a group of nonspecific disease conditions in which the principal clinical manifestation is diarrhea, and which are diagnosed and recorded in statistical reports as enterocolitis, enteritis, colitis, or diarrhea.

Etiology. Common diarrheas are caused by a number of different organisms, but principally by pathogenic members of the *Salmonella* group of bacteria. Owing to the fact that frequently typhoid and paratyphoid fevers, bacillary dysentery and amebic dysentery are not diagnosed and recorded as such unless the specific causal organisms can be found, many mild cases of these diseases are doubtless reported as common diarrhea. Also, in many instances, food infections are diagnosed as diarrhea because epidemiological evidence is lacking to show that they are attributable to a food infection.

Susceptibility and immunity. Generally, troops should be regarded as universally susceptible to diarrheal diseases, although it is probable that, as individuals, they possess varying degrees of immunity to the infections that constitute this group. There is some evidence that seasoned troops are, as a group, more resistant than recruits. Fatigue and depressing circumstances no doubt lower the resistance to these infections, even among well trained troops.

It is doubtful if an attack of common diarrhea confers more than a temporary and very transient immunity. Recurrences are frequent, but apparent recurrences may actually be new infections with different organisms.

Prevalence and importance. Under military conditions, diarrheal diseases tend to occur and to prevail wherever the sanitary protection of the food and water is inadequate. For this reason, diarrheas are particularly apt to be prevalent during or immediately after combat.

The prevalence of common diarrheas is determined almost entirely by environmental conditions. Seasonal influences apparently have no effect on the occurrence of these conditions, except in so far as climate and weather modify the environmental conditions and the activity of the troops.

The common diarrheas usually occur as sharp, limited epidemics, the extent of which depends to a considerable degree on the nature of the transmitting agent. Where the infecting organisms are transmitted by food, the spread of the disease is restricted to the consumers of the contaminated food. Water-borne epidemics are usually more extensive and, in the absence of suitable control measures, more prolonged. Sporadic cases may occur.

The common diarrheas are rarely fatal, and many of the milder cases are not hospitalized. They are of importance in the military service largely because of the time lost from duty by the more severe cases and the inefficiency resulting from mild infections.

During the World War, there were 87,774 cases of enterocolitis and diarrhea admitted to hospital, giving an annual rate per 1000 of 21.26. There were 195 deaths. The average time lost from duty was approximately eleven days for each case.

In 1933 there were 2555 admissions to hospital for enteritis, colitis and diarrhea from among 136,491 troops, an annual admission rate of 18.72 per 1000. In 1934 there were 2958 admissions for these conditions from 134,716 troops, an annual admission rate of 21.95 per 1000. In 1935 there were 3014 admissions from among 142,568 troops, an annual admission rate of 21.14 per 1000 troops.

Transmission. The diarrheal diseases are transmitted mainly by food and water. Flies no doubt play an important role in the contamination of food. Contact may at times be a factor in the transfer of the causal organisms.

The numerous mild cases afford many sources of infection. Food handlers having mild diarrhea are particularly important sources from which the infection may be transmitted to others through the medium of food. Occasionally, the causal agents may be transmitted by spoiled or unsound food.

Control measures. There are no specific measures for the control of the common diarrheas. The general measures for the control of intestinal diseases, such as water purification, food control, mess sanitation, and the proper disposal of wastes, will prevent any extensive prevalence of common diarrhea in military forces.

The occurrence of common diarrheas in a command is an indication of faulty environmental sanitation which will facilitate the spread of more serious diseases, such as dysentery and typhoid fever. Suitable control measures are, therefore, essential not only to control the spread of the milder diarrheal diseases, but also to prevent the occurrence of the more serious infections.

Proper diagnosis is one of the most important control measures. Where cases of diarrhea are present in an organization, every effort should be made to determine if the condition is actually dysentery, typhoid or paratyphoid fever, or some other infection, in order that specific therapy or specific prophylaxis may be used if available.

Concurrent and terminal disinfection. Concurrent and terminal disinfection procedures similar to those described under typhoid fever should be practiced in the care of cases of diarrhea in hospital.

FOOD INFECTION

(Salmonellosis, Food poisoning, Gastro-enteritis)

Definition. Food infection is a term used to designate an acute gastro-enteritis caused by the ingestion of food contaminated with certain specific organisms. It is characterized clinically by a sudden onset, symptoms of acute gastro-intestinal irritation as manifested by nausea, vomiting, diarrhea, and abdominal pain, and, in some cases, by symptoms of toxemia and prostration.

Etiology. Most of the reported cases and epidemics of food infection are caused by organisms belonging to the *Salmonella* group, including *S. enteritidis, S. aertrycke,* and *S. suipestifer. S. paratyphi* and *S. schottmuelleri* at times cause gastroenteritis which in the absence of other typhoidal symptoms would be diagnosed as food infection. *Staphylococcus* has also been found to be the etiological agent in a number of epidemics of food infection.

It is generally believed that food infections caused by *Salmonella* are due to the ingestion of the organisms rather than a pre-formed toxin. Some of the organisms of the *Salmonella* group produce toxins that are thermostable, or are at least able to resist a considerable degree of heat, and which will produce

toxemia in laboratory animals. Again, it is doubtful if these toxins are the etiological agents of food infections or that they are toxic when ingested by man.

The strains of *Staphylococcus* that cause food infection produce an enterotoxin which is pre-formed in the contaminated food. It is probable that this toxin, rather than the organisms, is the immediate cause of the symptoms of food infection.

Incubation period. The incubation period is short and the onset of symptoms usually occurs in less than twenty-four hours after ingestion of the infected food. The incubation period may be as short as two hours or, in rare instances, it may be longer than twenty-four hours.

Frequently, in epidemics where the staphylococcus is the etiological agent, many cases have an incubation period of only from two to four hours.

Susceptibility and immunity. Susceptibility to food infection is apparently universal and is not influenced by age, sex or race. While group susceptibility is high, as evidenced by the characteristically explosive outbreaks, it is seldom that all members of a group or organization who consume the contaminated food present symptoms of infection. Therefore, certain individuals are, undoubtedly, at times resistant to the infection, at least to moderate doses of the causal organism or toxin.

As far as can be determined, an attack of food infection does not confer immunity to subsequent attacks.

Prevalence and importance. Food infections usually occur as explosive epidemics and the spread of the disease is rather sharply limited to the consumers of the infected food. Where the infected food is served in an organization mess, practically all the cases occur among the men eating at that mess and the infection does not spread to the remainder of the command. Occasionally, a few cases may occur as the result of infection acquired through contact with other cases.

Food infections vary greatly in severity, not only in different epidemics, but also in the same outbreak. The symptoms may be mild and recovery may occur in a few hours. It is probable that many of the cases reported as diarrhea, gastro-enteritis or enteritis are in fact mild food infections. In other instances, a large number of men may be completely in-

capacitated for duty for several days. Fatalities seldom occur.

The results of studies conducted during recent years indicate that in many instances individual cases of illness diagnosed as gastro-enteritis or diarrhea, or small groups of such cases, are actually food infections due to staphylococci.

Food infection is important in the military service largely because of its disabling effect on an organization. As all the members of a company or similar military organization are fed at one mess, an entire organization may be exposed to infection at one time. The resulting epidemic is explosive in nature and widespread throughout the organization, and may interfere seriously with military activities at a critical time.

Epidemics of food infection occur at all seasons, but are more common during the warmer months. This is, however, largely due to the fact that troops are in the field to a greater extent in the summer and it is more difficult to secure proper protection of food during warm weather and under field conditions.

Transmission. Any food which will serve as a culture medium and promote the growth and continued existence of the infective organisms may be a transmitting agent and the immediate source of food infection. In the greater proportion of the epidemics of food infection that have been reported, the infection has been transmitted by meat or meat products, especially where the infective organisms belong to the *Salmonella* group. Vegetables, milk and milk products, fish and poultry are also frequently incriminated. Pastry, particularly such articles as cream puffs, custard, filled pies and cakes, eclairs, and other products of like nature, have been shown to be the source of infection in a number of epidemics of food infection caused by *Staphylococcus*. The infected food is not, necessarily, decomposed or altered with regard to taste, odor or appearance.

Mild or missed cases of food infection among food handlers are probably occasional sources of infection. Food may be contaminated by human carriers of *S. paratyphi* or *S. schottmuelleri* (*B. paratyphosus A* or *B. paratyphosus B*). The existence of human carriers of *S. enteritidis* and *S. aertrycke* has not been proven, and, in any event, they are rare.

Mice and rats may carry *Salmonella* organisms and discharge them in their feces and urine. It is quite probable that

in many instances the food of man is contaminated by the excreta of mice and rats.

In some instances, the causal organisms are of animal origin. The flesh of food animals which have been slaughtered while suffering from some disease condition, such as pyemia, septicemia or diarrhea, may be contaminated with and transmit the causal organisms of food infections. Meat and meat products which have been inspected and passed as suitable for food may be subsequently infected by contact with contaminated equipment or by the hands of the workers who handle the meat or meat products. Improper storage of meat products may promote the growth of the organisms causing food infections. The causal agents of food infections may enter milk in the feces of diseased cattle.

Shellfish which have been grown or stored in contaminated water, or handled under insanitary conditions, may transmit the etiological agents of food infections. Oysters are particularly dangerous in this respect as they are frequently eaten raw or but partially cooked.

Foods which have been cooked or otherwise prepared, and then allowed to stand at room temperature for some time before consumption, frequently serve as agents for the transfer of the infective organisms. This is particularly true of those foods which require considerable handling in the preparation, such as hash, salads, chopped meats, etc.

Control measures. The prevention of food infections is based on protection of the food from contamination. This is accomplished by the inspection and control of food products and by the proper protection of the food after receipt at the kitchens and messes.

Contaminated food may show no evidence of spoilage and epidemics of food infection may occur despite all reasonable precautions. However, food infection outbreaks are, as a rule, due to carelessness or lack of training on the part of some individual. Proper discipline and adequate training of all food handlers and the proper inspection of all foods are essential factors in the prevention of food infections.

All cooked foods in which bacteria will grow, such as meats, soups and vegetables, which have been left over from one meal should be recooked before serving at a subsequent meal. Dishes such as salads, hash or chopped meats, should

be prepared immediately before the meal at which they are to be served and not allowed to stand at room temperature for any considerable period of time. While refrigeration will inhibit the growth of the causal organisms of food infection, *S. enteritidis* will multiply at a temperature as low as 50°F.

The introduction of the fingers into food or the handling of food with the hands, especially food which will serve as a culture medium for bacteria, should be reduced to a minimum and all permanent food handlers should be thoroughly trained in this respect.

If pastries, especially the "filled" products are made in an army kitchen or bakery, particular attention should be devoted to the maintenance of scrupulous cleanliness. If such foods are purchased from civilian establishments, the operation of the bakeries concerned should be subject to adequate supervision by civilian health agencies or to thorough inspection by army inspectors.

All mice and rats should, as far as practicable, be eliminated from kitchens and messes, and food should be so stored that it will not be contaminated by the feces or urine of these animals.

When a food infection epidemic occurs, usually nothing can be done to modify or control the course of that particular epidemic, as the contaminated food has been eaten and infection has taken place. Every effort should, however, be made to determine the source of the infection in order to prevent future outbreaks. Epidemiological studies should be made to detect the article of food that served to transmit the causative agents and to determine the defect, if any, in inspection procedures or mess management which permitted the contaminated food to be served to the troops. Investigation of food infection epidemics should begin promptly after the occurrence of cases so that samples of the contaminated food may be obtained. Wherever practicable, laboratory studies should be made of the suspected food with a view to isolating and identifying the causal organism. The feces of patients should also be examined bacteriologically for the presence of the causal organisms.

BOTULISM
(*Food intoxication, Food poisoning*)

Definition. Botulism is an acute specific intoxication which is characterized chiefly by disturbances of vision, weakness, incoordination, paralysis of the muscles, and a high case fatality rate.

Etiology. Botulism is caused by the toxin of *Clostridium botulinum* (*Bacillus botulinus*). *Cl. botulinum* is a spore-bearing anaerobe which is found widely distributed in nature. The spores are present in the soil, on fruits and vegetables, and in dust. Its natural habitat is probably the intestinal tract of herbivorous animals. It grows readily at either incubator or room temperatures and produces a true exotoxin.

While *Cl. botulinum* may grow in the intestinal tract of man, botulism is produced by the ingestion of toxin which is pre-formed in the food before ingestion.

There are at least four types of *Cl. botulinum*—Type A, Type B, Type C and Type D. Type A predominates in the United States and Type B in Europe. Type C and Type D have not been found in the United States, and are not known to have caused botulism in man. Type A and Type B each produce a specific toxin and the toxin produced by one type is not neutralized by the antitoxin of the other.

The toxin of *Cl. botulinum* differs from other bacterial exotoxins, such as tetanus and diphtheria toxins, in that it is toxic when ingested. The toxins produced by most strains of *Cl. botulinum* are destroyed by exposure to a temperature of 176°F. for two minutes or to a temperature of 150°F. for thirty minutes.

The toxin of *Cl. botulinum* is a neurotoxin and is lethal in extremely minute doses. In many instances, a very small portion or even a taste of the contaminated food is sufficient to produce fatal intoxication. An antitoxin is produced by the injection of toxin into animals, usually horses. The antitoxin possesses both preventive and curative properties, but in order to be of therapeutic value, it must be administered early in the course of the disease or prior to the onset of symptoms. A polyvalent product containing both Type A and Type B antitoxins should be used.

Incubation period. As a pre-formed toxin is ingested there is no true incubation period. The symptoms usually ap-

pear within 18 to 36 hours after the consumption of the contaminated food, but the onset may be delayed for three days or longer. The length of the "incubation period" is determined to some extent by the amount of toxin ingested, but is usually short in severe cases.

Susceptibility and immunity. Man is universally susceptible to intoxication with the toxins of *Cl. botulinum*, Types A and B. Recovered cases probably possess immunity to the toxin but this point has not been fully determined.

Prevalence and importance. Botulism is rare in the United States, and is not nearly so prevalent as food infection. It occurs as explosive epidemics which are restricted to the consumers of the contaminated food. Botulism is important in the military service only because of its potentialities under military conditions. Owing to the relatively large number of men at a military mess, an epidemic might be widespread through an organization. The average fatality rate is about 60 per cent.

Transmission. The toxins of *Cl. botulinum* are, in the majority of instances, transmitted to man in canned, cured or otherwise preserved foods. Fresh foods are seldom, if ever, incriminated.

In the United States, botulism has usually been transmitted by canned vegetables or fruit, particularly those which have been canned in the home or on farms, and have not been properly processed. In Europe, most of the epidemics have been caused by the consumption of contaminated meat, especially sausage. As *Cl. botulinum* will grow in any protein food having a pH reaction above about 4.5, practically any food product, except acid fruits, will serve as a culture medium in which the toxin may be produced.

The food containing the botulinus toxin is usually contaminated with soil or other material bearing the spores of the organism before being canned or otherwise preserved, and is not heated sufficiently thereafter to kill the spores. Ordinarily, such food presents some evidence of spoilage. Gas, a putrefactive or butyric acid odor, or an off flavor taste is generally present and the food may be softened or decomposed. In some instances, however, no indications of spoilage can be detected by the untrained observer.

The toxin is destroyed by ordinary cooking. The temperature required to kill the spores varies with different strains of the organisms, but generally the spores are destroyed by exposure to a temperature of 110°C. (230°F.) for 15 minutes. If the spores are not killed, the toxin will be again produced in a detoxicated food if the food is allowed to remain at room temperature for several hours after heating.

Control measures. The prevention of botulism is based primarily on adequate supervision and control of the processes by which food for the troops is canned, cured or otherwise preserved. No food which has not been subjected to such supervision and control should be issued to troops and home canned or cured foods should never be used in any army mess.

No canned or cured food products which present any evidence of spoilage should be served. Mess personnel should be trained to inspect food with a view to the detection of such conditions (page 563).

All canned vegetables and canned or cured meat products should be heated sufficiently to destroy any botulinus toxins that might be present. If practicable, canned fruits should be heated before serving, but this cannot always be done. It is seldom feasible to heat canned foods to a temperature which will destroy the spores of *Cl. botulinum.* Consequently, any canned foods which are left over from one meal should, if practicable, be re-heated before being served at a subsequent meal, in order to destroy any toxins which may have been produced.

Any epidemic of botulism occurring in a command should be investigated epidemiologically in the same general manner as in the case of food infections (page 187).

If serum therapy is to be of any value, the diagnosis must be made promptly and the treatment instituted at once. Diagnostic tests are available, but as the diagnosis must be made without delay, it is usually determined by the history and the clinical symptoms. The Bengtson test consists of injecting one group of three mice with the Type A antitoxin, another group with Type B antitoxin, and leaving a third group unprotected by antitoxin as controls. Each group is then injected with 1.0 c.c., 0.5 c.c., and 0.1 c.c., of the suspected food material. If the injected material contains *Cl. botulinum* toxin, one or more mice in one of the groups receiving the antitoxin and one or more mice in the

control group should sicken and present symptoms of botulinus within a few hours.

If food containing botulinus toxin is fed to chickens, it will produce a characteristic condition known as "limberneck". The onset occurs within a few hours and is manifested by weakness of the neck muscles. Portions of suspected food may be fed to chickens as a diagnostic procedure, and as one means of detecting the transmitting food.

UNDULANT FEVER
(*Malta fever, Brucelliasis*)

Definition. Undulant fever is an acute infectious disease which is transmitted to man by goats, cows or hogs. It is characterized clinically by its long duration, irregular, intermittent and remittent fever, diaphoresis, pain in the joints and back, and prostration. The onset is usually insidious. Febrile attacks, with intervening periods of apyrexia, may occur over a period of months, or even years.

Etiology. Undulant fever is caused by organisms of the *Brucella* group. These organisms are classified as *Brucella melitensis* and *Brucella abortus*, and, by some workers, a porcine variety of *Brucella abortus* (*Brucella abortus-suis*). All are closely related and present only very slight cultural and serological differences. Goats are most commonly infected with *Br. melitensis*, cattle with *Br. abortus*, and hogs with the porcine variety of *Br. abortus*. *Br. abortus* is the causative agent of infectious abortion in cattle. Cattle may be infected with either of the three varieties and hogs may be infected with the bovine strain as well as the porcine strain. Each of the three strains has been isolated from mares. It is also known that sheep, mules and dogs may harbor the infection. Man may be infected with either *Br. melitensis* or *Br. abortus*. All strains are destroyed when subjected to a temperature of 140°F. for 15 minutes.

Incubation period. The incubation period of undulant fever is generally assumed to be from ten to eighteen days. Usually, the insidious onset and the indefinite date of exposure render it difficult to determine the length of the incubation period. In some instances, the onset has apparently occurred in not more than six or seven days after exposure.

Susceptibility and immunity. The epidemiology of undulant fever indicates that the infectivity of the causal organism is low or that man possesses a considerable degree of resistance to the infection. Apparently, man is more susceptible to *Br. melitensis* and to the porcine variety of *Br. abortus* than he is to *Br. abortus*.

It is generally considered that one attack of undulant fever confers permanent immunity against future attacks. However, some difficulty has been encountered in determining whether recurrences of the disease were due to re-infection or constituted relapses or recrudescences of a pre-existing infection.

Prevalence and importance. Undulant fever occurs as sporadic cases, or as localized epidemics consisting of only a few cases. It occurs generally throughout the United States and Europe, and is probably much more prevalent than is shown by the reported incidence. Undoubtedly, many cases are missed by being wrongly diagnosed as some other disease, especially typhoid fever, malaria, tuberculosis or influenza.

Undulant fever seldom occurs among children under five years of age and the incidence is the greatest among young adults. In rural districts, the incidence is much higher among men than among women, due probably to the fact that the exposure rate is higher among men who work with infected hogs and cattle.

In the military service, sporadic cases are occasionally reported and, in most instances, the infection is traceable to milk.

Transmission. The causal organisms of undulant fever are transmitted to man in cow's milk or in goat's milk, also in the excreta from cattle, hogs and goats, and by inoculation through direct contact with the flesh of these animals, especially hogs.

In the United States, undulant fever is contracted through drinking raw cow's milk, or by contact with hogs and cattle. The disease is acquired from goats only in localities along the southern border. It is possible for undulant fever to be transferred from one person to another in excreta, as the organism has been found in the feces of those sick with the disease.

Cows which have had infectious abortion may eliminate *Br. abortus* in the milk for considerable periods of time. In milk, the organisms tend to concentrate in the cream. *Br. abortus*

will remain viable in cream for eight to ten days and in butter for as long as four or five months when the butter is stored at a temperature of 46°F. Apparently, relatively large doses of the organisms are required to produce undulant fever in man, and not all contaminated milk contains the organisms in sufficient numbers to cause infection.

Persons who handle the flesh of infected animals may be infected by inoculation through the skin. A number of cases have occurred among workers in meat packing establishments and among farmers who handle and slaughter hogs. It is probable that the infection is frequently transmitted from animals to man by the inoculation of infected excreta through abrasions in the skin.

The infection may be transferred by the ingestion of food other than milk, and possibly also by water which is contaminated with the excreta of infected animals.

Control measures. The control of undulant fever is based primarily on the control and ultimate elimination of infected animals. Progress is being made with a view to eradicating the disease from among dairy cattle, but little has been done, as yet, to control the infection among hogs.

Pasteurization will prevent the transmission of the organisms in milk. Meat inspection is the principal safeguard against the transmission of the disease by infected pork or other meats. Vaccination with killed organisms has been tried but has afforded little, if any, protection against the disease.

Each case of undulant fever occurring among troops should be investigated to determine the source of the infection, with a view to preventing the spread of the disease from the same source.

Particular attention should be given to the diagnosis of undulant fever so that all sources of infection may be found and corrected. The organisms are present in the blood during the early stages of the disease and if undulant fever is suspected, a blood culture should be made. An agglutination test should be done on the blood serum of every patient presenting symptoms which might be indicative of undulant fever. A positive agglutination test in dilutions of 1:80 or higher will, in the presence of clinical symptoms, justify a diagnosis of undulant fever. Usually, agglutinins are not present in the

blood serum until one or two weeks after the onset of the fever. The test should be made at the end of the first week of fever and if negative, it should be repeated at the end of the second week. If negative again, and the fever continues, a third test should be made at the end of the third week. There are occasional cases in which the agglutinins do not develop or positive reactions are not obtained in dilutions higher than 1:10. In these cases the diagnosis must be determined by clinical symptoms or the results of blood culture. A test based on the reaction to an intradermal injection of suspensions of killed *Br. abortus* has been used as a diagnostic procedure.

Concurrent and terminal disinfection. The concurrent and terminal disinfection measures employed in the care of patients with intestinal diseases are generally applicable in the care of undulant fever patients (page 155). Particular care must be taken, however, to prevent the transmission of the infection to attendants and nurses by inoculation.

TRICHINOSIS
(*Trichiniasis, Trichinelliasis*)

Definition. Trichinosis is an acute disease caused by the nematode worm *Trichinella spiralis.* It is characterized clinically by irregular and variable symptomatology. Typical symptoms include remittent fever, gastro-intestinal disturbances, muscular pain and tenderness, particularly in the muscles of the extremities, edema of the face, anemia and emaciation. There is a marked leukocytosis, which may be as high as 30,000. Eosinophilia is characteristic of the disease and may reach 50 per cent or more. A suborbital edema is frequently a characteristic symptom of trichinosis.

Atypical cases are the rule rather than the exception. The degree of infestation with trichinae may be light, intermediate or heavy, and the parasites may invade any of the soft tissues of the body. Consequently, the character, and to some extent the severity, of the symptoms depends upon the number of trichinae present and their location in the body.

Etiology. *Trichinella spiralis* has its natural habitat in the small intestine of carnivorous and omnivorous mammals, especially hogs, rats, mice, dogs, cats and man. Infestation does not

occur naturally in birds, fish, reptiles, invertebrates or herbivorous animals.

The adult *Trichinella spiralis* is a minute white worm which can barely be seen with the naked eye. The male is about 1.5 mm. (1/17 inch) long and 0.04 mm. in diameter. The female is 2 to 4 mm. (1/12 to 1/6 inch) in length and about 0.06 mm. in diameter. It is viviparous.

Two hosts are required in the life cycle of *Trichinella spiralis*. Briefly, the female worm in the intestine of the infested animal gives birth to embryos, or larvae, which penetrate the intestinal wall and eventually reach the skeletal muscles where they become encysted. When another animal eats the muscular tissue containing the encysted larvae, the larvae develop into adult forms in the intestine of the new host and the life cycle is thus completed.

When man ingests meat containing the live encysted larval forms of *Trichinella spiralis* (*infra*) the cyst walls are digested and the worms are set free in the intestine. Copulation takes place and the fertilized females burrow into the intestinal mucosa. The females give birth to embryos in about a week after ingestion of the trichinous meat. The embryos pass in large numbers through the lymphatics into the blood and eventually to the soft tissues, especially the voluntary muscles, where encystation takes place. The embryos reach the muscles in about ten days after ingestion of the larval forms.

In the tissues, the embryo continues to grow and development is complete in about two weeks, at which time it is about 1/25 of an inch in length. It then coils up to form the characteristic spiral and becomes enclosed in an oval or lemon shaped cyst, which is usually about 1/60 of an inch (400 microns) in length. The cyst wall is formed by the reaction of the tissues to the presence of the parasite. When the cysts containing the living larvae are ingested by another animal, the cycle starts anew. The cysts may live in the muscles unchanged for a period of five years or longer, but ultimately become calcified. In moderate infestations, the encysted larvae may be present in enormous numbers in the muscles.

The female worm in the intestinal canal continues to give birth to embryos for a period of about six weeks, although most of the embryos are born during the first two weeks. A single worm will give birth to from 1000 to 2000 embryos.

A skin test and a precipitin test are available as diagnostic aids. However, the skin test does not give a positive reaction until from eleven to fourteen days after infestation. The precipitin test does not usually become positive until the fourth week after infestation. Both tests may remain positive for an indefinite period of time after recovery.

Incubation period. In relatively heavy infestations, the incubation period of trichinosis in man is usually from one to two weeks. The onset of the symptoms may occur within three or four days after ingestion of the trichinous meat, or the incubation period may be prolonged to from two to three weeks. During the early stages of the disease, while the worms are developing in the intestine, there may be diarrhea and other gastro-intestinal symptoms. This period is followed by the development of the characteristic clinical manifestations consisting of fever, pain in the muscles, suborbital edema, and symptoms of toxemia.

Susceptibility and immunity. Man is apparently universally susceptible to trichinosis and, as far as is known, an attack of the disease does not confer immunity to future attacks.

Prevalence and importance. It is generally believed that trichinosis is much more common than the number of reported cases would indicate. The diagnosis of trichinosis in man can usually be definitely made only when the larval forms are found in muscle tissues, or possibly in the blood. Consequently, it is probable that many cases of mild infestations are missed and that severe cases are more or less frequently confused with some other condition. The incidence of trichinosis is governed largely by the customs of the people with regard to the consumption of raw or partially cooked pork products. Hall and his co-workers estimate that at least 12.5 per cent of the general population of the United States are infested with trichinae at some time during life. The results of meat inspection indicate that from one to two per cent of the hogs in the United States are infested with *Trichinella spiralis*, and it is entirely probable that the actual incidence of infestation among hogs is considerably higher.

In the United States the case fatality rate during recognized epidemics of trichinosis is about five per cent, although the severity of the disease in the case of any one patient depends to a considerable extent on the degree of infestation.

Transmission. Man contracts trichinosis in practically all instances by eating raw or improperly cooked pork containing the living encysted larvae of *Trichinella spiralis.* As a rule, the living larvae are transmitted in those cured pork products which are eaten raw, or but partially cooked, such as certain kinds of sausages and hams.

Hogs are infested mainly by eating offal, or pork scraps in garbage, which contain the encysted forms of the parasites and the garbage fed hog is the principal source of infestation in man. Hogs may be occasionally infested by killing and eating infested rats. The infestation is not transmitted by the excreta.

Man is not a source of infection and is not a factor in the dissemination of the infestation either to other persons or among animals. It is probable that hogs and rats constitute the principal reservoirs from which trichinosis is spread among animals.

Control measures. Meat inspection is not an adequate safeguard against the transmission to man of *Trichinella spiralis.* There is no method by which the encysted larvae can be detected in meat except by microscopical examination, and such an examination is not ordinarily practicable. For this reason, Federal Meat Inspection procedures do not specifically include inspection for infestation with *Trichinella spiralis.*

The encysted larvae are killed by a temperature of 5°F. for twenty days, but are resistant to ordinary chilling. The Federal Meat Inspection regulations require that all pork muscle tissue which is to be eaten raw shall either be held for twenty days at a temperature not higher than 5°F. or heated to a minimum temperature of 137°F.

Ordinary cooking destroys the parasite, but it is essential that the meat be cooked sufficiently to allow the heat to penetrate to and raise the temperature of all parts to at least 137°F. Large hams which are not cooked for a sufficient time to kill the encysted trichinae at or near the center are especially dangerous.

ANKYLOSTOMIASIS

(Uncinariasis, Necatoriasis, Hookworm disease)

Definition. Ankylostomiasis is an infectious disease caused by the parasitic intestinal worms, *Necator americanus* and *Ankylostoma duodenale.* The more severe cases of infestation are characterized clinically by anemia and physical weakness,

and in children by retardation of mental and physical development. Mild infestations may cause no demonstrable clinical manifestations. Eosinophilia is usually present, but may be absent even in heavily infested cases.

Etiology. The species of hookworm which infest man (*Necator americanus* and *Ankylostoma duodenale*) have their natural habitat in the small intestine of man. The worm is attached by the mouth parts to the intestinal wall and subsists on blood drawn from the tissues to which it is attached. It secretes a substance which prevents coagulation of the blood in the wound made by the bite. The clinical symptoms of hookworm disease are caused by loss of blood and are probably also due in part to a toxin secreted by the worm.

From twenty-five to fifty worms of the species *Necator americanus* must be present in order to produce the symptoms of hookworm disease. Usually, those who present moderate to severe symptoms are infested with from one hundred to a thousand worms. Individuals who are infested but do not present demonstrable symptoms are known as carriers.

Prevalence and importance. *Ankylostoma duodenale* is found in Europe and Asia and *Necator americanus* in the Western Hemisphere and in Africa. Warmth and moisture are required for the development of the hookworm outside the body, and, consequently, hookworm disease is most prevalent in tropical and sub-tropical regions and in the warmer portions of the temperate zones. In general, hookworm disease prevails in the belt lying between the latitudes of 38°N. and 35°S. It may, however, occur in other regions where environmental conditions are suitable for the development of the worms.

Cases of heavy infestation with hookworms are relatively rare among troops. Owing to the physical requirements which must be met by those entering the army, heavily infested men are not ordinarily enlisted or inducted into the service. Light and moderate infestations are, however, fairly common among men drawn from districts in which hookworm disease prevails in the civilian population.

The examination of recruits during the World War showed that approximately seventeen per cent of the men of military age from the southern states, that is from the area included in Maryland, Virginia, Kentucky, Missouri and all states south of them, were at that time infested with hookworms. Surveys of men

from other sections of the country yielded only a small percentage of positive results.

Hookworm infestation, even when very light, impairs the physical efficiency of the individual and may, in some instances, increase his susceptibility to infection. Consequently, aside from the problem of controlling hookworm disease *per se*, the eradication of hookworm infestation may be an important phase of military preventive medicine in connection with other measures for promoting physical fitness and controlling disease.

Transmission. The ova of the female hookworms are deposited in the intestine and are discharged in the feces. The eggs are oval, segmented, translucent bodies about 60 microns in length by 35 microns in breadth. They are easily discernible and readily recognized under the low power microscope. The ova require oxygen for development and do not, therefore, hatch under the anaerobic conditions existing in the intestine.

In moist, warm soil the ova hatch in from twenty-four to forty-eight hours and the motile free-living larval form emerges. The larvae feed on organic matter. They moult twice and develop into the mature or infective form in from four to five days to a week. The mature form is ordinarily encysted in a sheath, although some authorities have found that a considerable proportion of the mature larvae may not be ensheathed. Both the ensheathed and unensheathed forms are infective. The mature larvae are capable of rapid movement but tend to remain quiescent unless disturbed. They are about 500 microns in length and 25 microns in diameter.

Larval development is retarded by a temperature of 60°F. or less and ceases at 40°F. The optimum temperature is about 85°F. The larvae die if exposed to sunlight or if the feces in which they are contained are diluted with water.

Mature larvae may survive under suitable conditions for long periods of time. It has been shown, however, that under ordinary conditions in tropical regions, the larvae do not ordinarily live for more than six weeks, but may live as long as three months.

The mature larvae infect man by penetrating the skin, usually the skin of the feet or lower portions of the leg. The most common site of penetration is between the toes. Penetration cannot take place unless the bare skin comes in con-

tact with infected soil, and hookworm infestation is found most frequently among persons who go barefooted. Penetration of the skin by the hookworm larvae causes a local irritation which is sometimes known as "ground itch".

After passing through the skin, the hookworm larvae burrow through the tissues and enter the lymphatics and veins by which some are eventually carried to the lungs. From the lung tissues, the larvae pass up the bronchi and trachea to the throat and are swallowed and thus reach the small intestine. Probably many of the larvae are lost in the tissues and never reach the throat, while many of those that do reach the throat are expectorated.

In the small intestine the larvae penetrate into the mucosa where, after passing through one or two moults, they develop into sexually mature adult worms. The passage from the point of penetration through the skin to the intestine requires from seven to ten days, and development to the mature adult worm about 30 days. The adult worm begins to lay eggs in about five to six weeks after infection.

The male hookworm is about one-third inch and the female about one-half inch in length. *A. duodenale* is slightly larger than *N. americanus* and there is some slight variation in size within each species.

Most of the adult worms are eliminated from the intestine within a few months to a year, but some may remain for as long as from seven to ten years. They do not reproduce in the intestine, and all increase in infestation results from contact with sources of infection outside the body. Thus, heavy infestation usually occurs only when there is long continued exposure to contaminated soil. Conversely, the number of worms in the intestine decreases as exposure decreases or ceases.

The infective larvae may be ingested and swallowed and will then produce infestation in the same manner as when they enter the body through the skin. They may be carried to the mouth by the hands, by contaminated food or, possibly, by water. Vegetables grown in contaminated soil and eaten raw may transmit the infection. Normally, however, contaminated soil is the principal source of infestation, and infection by ingestion of the larvae is relatively rare, and would not, ordinarily, result in heavy infestation.

Control measures. Hookworm control in a civilian population is based on the proper disposal of excreta, the treatment of large groups of people to reduce the number of worms carried per individual, and the wearing of shoes. Control in the army is a relatively simple procedure. As all soldiers wear shoes and as excreta is disposed of in latrines so that it does not contaminate the surface of the soil, troops are not subjected to exposure to hookworm infestation. Consequently, the number of worms carried by an individual tends to decrease after entry into the service. Nevertheless, all men who are enlisted into the army from districts in which hookworm disease is prevalent should be examined for hookworm infestation in order that they may be given proper treatment.

Where large numbers of troops are concerned, complete hookworm surveys of companies or larger units should be made. In the conduct of such a survey, a specimen of feces is collected at a given time, usually at reveille, from each member of the unit being surveyed. Feces collections should be made under supervision of Medical Department personnel.

In preparing the specimen of feces for microscopic examination some method of concentrating the eggs should be employed. Otherwise, many cases of light or moderate infestation will escape detection. Any one of a number of procedures may be employed for this purpose. The brine flotation-loop method has been found to be generally satisfactory where large numbers of specimens are to be examined. A rather large sample of feces is placed in a two or three ounce container and thoroughly emulsified in a saturated solution of sodium chloride. A disk made of No. 0 steel wool is placed horizontally on the surface of the contents of the container and, in sinking, forces the coarse floating material below the surface. The ova float upward through the interstices of the disk and are concentrated on or near the surface of the liquid. After placing the steel wool disk, the mixture should be allowed to stand undisturbed for not less than ten minutes nor more than one hour. A part of the surface film is then looped off with a wire loop and placed on a slide for examination. The loop used for this purpose should be from one-fourth inch to one inch in diameter. No cover glass is used. If the emulsion is allowed to stand for longer than one hour the ova tend to sink away from the surface. Where large numbers of speci-

mens are to be examined, the ordinary paraffined paper drinking cup makes a satisfactory container and may also be used for collecting the specimens.

A glucose solution may be used instead of brine. A small amount of feces is emulsified in water in a small test tube. Then several cubic centimeters of a saturated solution of sugar are added to the emulsion. The ova float to the surface and can be removed from the surface film with a small wire loop, care being taken to apply the loop to all parts of the surface film and especially where it touches the sides of the tube. As compared with brine, the sugar solution has the advantage that the ova will not sink away from the surface and the emulsion may be allowed to stand for twenty-four hours or longer.

The Barber method may be used where but few examinations are to be made. A small amount of fecal material is placed on a slide and emulsified in a solution consisting of equal parts of saturated salt solution and glycerin. The ova rise to the surface of the liquid where they can be easily detected under the low power microscope.

Where it is desirable to determine the degree of infestation, either during the progress of a survey or as a guide to treatment, some method of estimating the number of worms harbored by each individual may be utilized. Usually, such an estimate is based on egg counts and the Stoll dilution method is a satisfactory procedure for this purpose. Three grams of feces are placed in a large test tube which is graduated at 45 c.c. The tube is then filled to the 45 c.c. mark with a decinormal solution of sodium hydroxide, closed with a rubber stopper and vigorously shaken. The shaking must be sufficient to produce a homogeneous suspension of the fecal material. A few glass beads may be placed in the tube to facilitate the comminution of the feces. When a homogeneous suspension has been obtained, exactly 0.15 c.c. is removed with a graduated pipette, placed in the center of a glass slide and covered with a cover glass. The ova are then carefully counted under a microscope, using the low power. A mechanical stage must be used and care taken to locate and count all of the ova. The number of eggs found in the 0.15 c.c. portion multiplied by 100 represents the number of ova in one gram of compact, formed feces. According to Stoll, when the number of eggs present in one gram of formed feces is divided by

22, the figure obtained represents the approximate number of hookworms, male and female, carried by the person from whom the specimen was obtained. In all the calculations used above it is assumed that the specimen examined consists of formed, compact feces. If the specimen is soft or mushy the results are multiplied by two. If the feces are watery in consistency, the results are multiplied by four.

All men found to have hookworm ova in their feces should be given proper treatment. Where practicable, re-examinations should be made and additional courses of treatment given if required.

OTHER HELMINTHIC INFESTATIONS

The helminths (worms) are the causal agents of a number of pathological conditions in man. The most important of these conditions, so far as American troops are concerned, are ankylostomiasis, trichinosis and infestation with tapeworms (*taeniasis*). Other diseases due to helminths which might occur among American troops are filariasis, schistosomiasis and possibly hydatid disease. Individuals may occasionally be found to be infested with other worms, such as *Ascaris lumbricoides, Oxyuris vermicularis* or *Trichuris trichiura*. Trichinosis and ankylostomiasis are discussed on pages 194 and 197, respectively. Filariasis is considered in Chapter XX.

Tapeworms (*Taenia saginata, Taenia solium, Diphyllobothrium latus, Hymenolepis nana, Taenia echinococcus*). The tapeworms belong to the class Cestoda. The adults are flat, ribbon-like endoparasitic worms which live in the intestinal canal of man and certain of the lower animals. The adult worm consists of a scolex or head and a segmented body. The scolex is provided with a suction apparatus for attachment to the intestinal wall. There may be two slit-like or four round, cuplike suckers. In some species the scolex is armed with a circlet of hooks (rostellum), while others are unarmed.

The scolex is attached to the body by a narrow unsegmented neck. The body consists of a series of flattened segments or proglottides. Each segment is bi-sexual, containing both the male and female organs. As a segment develops the male elements disappear so that the ripe segment is composed almost entirely of the gravid uterus and its contained eggs. Nutrition is pro-

vided by osmosis through the body surface of the worm. New, immature segments arise from the scolex and, as they develop, form a chain-like structure with the mature and ripe segments at the caudal extremity.

Taenia saginata (*Beef tapeworm, unarmed tapeworm*). The normal habitat of the adult *Taenia saginata* is in the upper part of the small intestine of man. Man is the definitive host and usually only one worm is present.

The adult worm is from ten to thirty feet long or longer and the body may consist of as many as 1000 to 2000 proglottides. The scolex is cuboidal or pear shaped. It has four hemispherical suckers, but no hooks or rostellum. The scolex is from one to two millimeters in diameter. The ripe proglottides are from 12 to 25 mm. in length and 4 to 7 mm. in width. The eggs are from 35 to 40 microns long and from 20 to 30 microns in diameter. The egg has a thin and transparent outer shell, while the inner shell is thick and striated and encloses a six-hooked embryo, or *onchosphere.*

The ripe proglottides become detached from the posterior extremity of the adult worm and are discharged from the body in the feces or, as the proglottides are motile, they may reach the exterior by crawling through the anal opening. Free eggs may also be passed in the feces.

Outside the body the proglottides crawl into the grass or herbage where they disintegrate. The eggs are ingested by cattle, which are the intermediate hosts for the worm. The onchospheres become free in the intestinal canal and pierce the intestinal wall to reach the muscular tissues, especially the muscles of mastication, the diaphragm, tongue and heart, where they become encysted. The encysted form is known as *Cysticercus bovis. Cysticercus bovis* is an oval, bladder-like body containing fluid and the invaginated scolex. It is 7 to 10 mm. in length by 5 to 6 mm. in diameter. The cysticerci are sometimes known as "beef measles" and beef containing cysticerci is called "measly beef".

When beef containing a living cysticercus is ingested by man, the bladder is digested and the scolex becomes attached to the wall of the small intestine by means of the suckers. The adult worm then develops by the formation of proglottides from the scolex.

Prevalence and importance. The distribution of *T. saginata* is world wide. Infestation of man occurs most frequently among persons who habitually consume raw or improperly cooked beef. It is estimated that slightly less than one per cent of the cattle in the United States are carriers of cysticerci.

Clinically, infestation with *Taenia saginata* is of relatively minor importance. Intestinal disturbances of a minor nature and a mild grade of anemia may be produced. Infestation may be the cause of lowered physical efficiency and a decrease in resistance to disease.

Transmission. Man becomes infested with *Taenia saginata* only through the ingestion of beef containing living *Cysticercus bovis.* Autoinfestation, with the development of the larval forms in the tissue, does not occur in the human host. In this respect *T. saginata* differs from *T. solium* (the pork tapeworm).

Control measures. Infestation of man with *Taenia saginata* is prevented by inspection of beef for the presence of cysticerci and thorough cooking of all meat. The cysticerci die within three weeks after the death of the host, so that infested beef can be rendered safe for consumption by being kept in cold storage or pickled for a period of three weeks. As the cysticerci are killed by exposure to a temperature of 15° F. or lower for six days, the storage period may be reduced to six days if the temperature is maintained at 15° F. during that time.

Taenia solium (*Pork tapeworm, armed tapeworm*). The adult *Taenia solium,* or pork tapeworm, is found only in man. Usually, only one worm is present. The adult worm is generally somewhat smaller than *T. saginata* and varies in length from an average of 10 to 12 feet to possibly as much as 25 to 30 feet. The head is globular and is provided with four suckers and an armed rostellum bearing a double crown of from 25 to 50 hooks. The ripe proglottides are from 10 to 12 mm. long and from 5 to 6 mm. broad. They are discharged in the feces, usually in lengths of from three to six proglottides.

The eggs of *T. solium* resemble those of *T. saginata.* They are slightly oval in shape, from 30 to 50 microns in diameter, and have a double shell enclosing the six-hooked embryo or onchosphere. The mature, ripe proglottides of *T. solium* may be differentiated from those of *T. saginata* by the character of the lateral uterine branches. The uterus of *T. solium* has from seven to twelve thick dichotomous branches on each side. The uterus of

T. saginata has from 18 to 30 branches on each side which rebranch and ramify.

Outside the body the proglottides disintegrate and the eggs are ingested by the pig, which is the normal intermediate host of *T. solium.* The onchospheres are set free in the alimentary tract of the pig and bore through the intestinal wall to reach the blood stream by which they are carried to the muscular tissues of the body. In the muscular tissues the onchosphere develops into an oval, bladder-like body called the *Cysticercus cellulosae* which contains fluid and an invaginated scolex and neck. The cysticerci of *T. solium* are usually about one-half inch long and are slightly larger than those of *T. saginata.* Infested pork is frequently speckled with *C. cellulosae* and is sometimes called "measly pork". The disease in hogs is also known as "pork measles". Hogs are usually much more heavily infested with *C. cellulosae* than cattle are with *C. bovis.*

When a living *Cysticercus cellulosae* is ingested by man, the bladder wall is digested and the scolex released. The scolex attaches itself to the intestinal wall and the adult worm develops in the same manner as *T. saginata* (*supra*).

Man may serve as an intermediate as well as the definitive host for *T. solium.* If the eggs are ingested by man, or reach the stomach by reverse peristalsis, the onchospheres are set free and invade the intestinal wall. They are carried by the blood stream to various parts of the body where they develop into cysticerci in the same manner as in the hog. In man the cysticerci may be found in any organ, especially in the muscles, brain, eye, liver, heart and lungs.

Prevalence and importance. Infestation with *T. solium* is rare in the United States. It is more common in the tropics and in Europe. Pork infested with *Cysticercus cellulosae* is much less frequently found during meat inspection than is beef infested with *Cysticercus bovis.* The prevalence in man is influenced by the degree of close association between man and hogs and by customs relative to the consumption of raw or partially cooked pork.

Infestation with *T. solium* is much more serious than infestation with *T. saginata* because of the danger of the cysticerci of *T. solium* developing in the muscles and organs of the human host. Otherwise, the clinical symptoms produced by the pres-

ence of *T. solium* in the intestinal tract are similar to those found in infestation with *T. saginata.*

Transmission. Man becomes infested with the adult *Taenia solium* by eating raw or improperly cooked pork containing living cysticerci. Infestation with *Cysticercus cellulosae* is due to the consumption of food or water contaminated with the eggs of *Taenia solium.* The carrier of the adult worm may become infested with *C. cellulosae* by carrying the eggs on his hands from his own feces to his mouth.

Control measures. Primarily, the infestation of man with *Taenia solium* is prevented by the inspection of pork for the cysticerci and by thorough cooking of all pork products. The cysticerci live for a considerable period of time after the death of the intermediate host and refrigeration cannot, therefore, be depended upon to destroy them. They are resistant to chilling but are readily killed by ordinary cooking temperatures.

A case of human infestation with the adult *T. solium* should be isolated and receive prompt treatment in order to prevent the transfer of the eggs to others and also to prevent auto-infestation.

Diphyllobothrium latus (*Fish tapeworm, broad tapeworm*). The adult *D. latus* is found in the small intestine of man, dog, cat and fox. Multiple infestations are relatively common in man. The scolex is about three millimeters long by one millimeter in width and is equipped with two slit-like suckers or grooves, called bothria. It has no hooks or rostellum. The body consists of from 3000 to 4000 proglottides or segments and the worm may reach a length of 30 feet or more.

The eggs are, as a rule, released from the proglottides in the intestinal canal of the definitive host and discharged from the body in the feces. As eggs are being released from all the mature proglottides at the same time, they are usually present in the feces in large numbers. The aged proglottides become detached in chains, but usually contain only a small number of eggs when passed in the feces.

The eggs are elliptical in shape. They are operculated and measure about 70 microns in length by 40 to 50 microns in diameter. In order to develop, the eggs of *D. latus* must reach water containing the intermediate hosts. After about two to three weeks in water the eggs hatch and a free swimming, ciliated onchosphere escapes through the operculum and is ultimately

ingested by certain fresh water crustacea (*Cyclops*). The onchosphere develops into the procercoid form in the body cavity of the cyclops host. The cyclops is in turn swallowed by a fish—the second intermediate host. The procercoid larva penetrates through the stomach of the fish and becomes encysted in the muscular and connective tissue as the plerocercoid larval form. The plerocercoid larva is a worm-like organism from one-fourth to one-half inch or more in length. It remains encysted and dormant in the tissues of the fish until ingested by a definitive host, which may be either man or one of the lower animals.

When the living plerocercoid is ingested by man, or other definitive host, it becomes attached to the intestinal wall and develops into the adult worm. A period of from five to six weeks is required for the development of the adult worm. The adult may live for many years, possibly ten or more.

Prevalence and importance. In the United States infestation with *D. latus* occurs among the inhabitants of the Great Lakes region. In man, infestation with *D. latus* is accompanied by symptoms similar to those observed in cases of infestation with *Taenia saginata*, except that occasionally a severe anemia is produced.

Transmission. The living plerocercoid or larval form of *D. latus* is transmitted to man only in the raw or improperly cooked flesh of fresh water fish, which in the United States is usually pike or perch obtained from waters in the vicinity of the Great Lakes. Autoinfestation, or the transfer of the infective forms directly from person to person, does not occur. Consequently, neither the procercoid nor the plerocercoid stage is found in man, and man does not serve as an intermediate host for the worm.

Control measures. Infestation with *Diphyllobothrium latus* is prevented by the inspection of all fresh water fish for the plerocercoid forms and by thoroughly cooking all fresh water fish served to troops. The plerocercoids are not killed by drying, smoking, salting or freezing.

Hymenolepis nana (*Taenia nana, dwarf tapeworm*). *Hymenolepis nana* is generally considered to have its normal habitat in the small intestine of man. *Hymenolepis nana fraterna*, which is found in rats and mice, is indistinguishable from *H. nana* and may be transmissible to man. It may be that rat fleas are concerned in the transmission of the larval forms from rats to man.

H. nana is the smallest of the tapeworms, the adult forms of which commonly infest man. The adult worm measures from 25 to 40 mm., rarely as much as 45 mm., in length and from 0.5 to 1.0 mm. in width. The scolex is globular or subglobular in shape and from 0.13 to 0.48 mm. in diameter. It has four suckers and a rostellum bearing a single crown of 20 to 30 hooklets.

The neck is long and slender and the body consists of from 100 to 200 proglottides. The mature proglottides are from 0.5 to 1.0 mm. wide and from 0.14 to 0.3 mm. long. The egg is oval in shape, from 30 to 50 microns in diameter, and is provided with two distinct membranes. There is a rather conspicuous mammillate projection from each pole of the onchosphere. The onchosphere has three pairs of embryonic hooks.

The terminal, ripe proglottides, which are almost completely filled with eggs, apparently begin to disintegrate and release the eggs while attached to the rest of the worm, or when detached from the parent worm they are partially digested and the eggs released into the intestinal canal. The eggs are discharged from the body of the host in the feces.

No intermediate host is required in the life cycle of *H. nana.* The egg is ingested by man and the embryo or onchosphere is set free in the small intestine where it burrows into a villus. Here it develops into the cercocystic or cysticercoid form. It then passes from the villus into the lumen of the intestine and becomes attached to the intestinal wall, after which the adult worm develops. The complete life cycle requires about four weeks. It is possible that in some instances the eggs which are set free in the intestinal canal hatch and the embryos enter the villus of the intestine without the eggs passing to the exterior.

Prevalence and importance. Hymenolepis nana is probably the most common tapeworm in the United States. It is much more prevalent among children than among adults. It is more common in the tropics than in colder regions. Usually, infestation with *H. nana* produces no clinical symptoms, but if symptoms are present, they are similar to those described for *T. saginata,* except that there may be evidence of involvement of the nervous system. Heavy infestations may occur and a single person may be infested with as many as 100 worms.

The diagnosis is made by finding the eggs in the feces. As the eggs are small and somewhat transparent, they are frequently overlooked during fecal examinations.

Transmission. The eggs of *H. nana* are transferred directly from person to person on the hands and in food or drink contaminated with fecal material containing the eggs. Additional infestation results when the infested individual carries the eggs on his hands from his own feces to his mouth. As described above, autoinfestation may occur within the intestinal canal of an infested person.

Control measures. Control measures consist of protecting food and drink from contamination with fecal material. The eggs are destroyed by cooking.

Prompt and thorough treatment should be given a person in whose feces the eggs of *H. nana* are found in order to prevent the infestation of others, and also to prevent autoinfestation.

Taenia echinococcus (*Echinococcus granulosus, hydatid tapeworm*). *Taenia echinococcus* in its larval form is the causal agent of hydatid disease (*Hydatid cysts, echinococcus cysts*) in man. The adult worm has its natural habitat in the small intestine of the dog and other carnivora, such as the fox, wolf or jackal. *T. echinococcus* is one of the smallest of the tapeworms, being only from 2.5 to 6 mm. in length. The scolex is globular and about 0.3 mm. in diameter. It has a rostellum which is armed with a double row of hooklets. The neck is short and the body consists of not more than four proglottides. The posterior proglottis is about one-half as long as the entire worm. It is the only one of the proglottides which is mature and it contains about 800 eggs.

The mature proglottis is passed in the feces and disintegrates, releasing the eggs, or the eggs are set free in the intestinal canal of the definitive host and discharged in the feces. The eggs are slightly ovoid in shape and measure about 35 microns in length by 25 microns in diameter. The onchosphere has three pairs of embryonic hooks.

The eggs are ingested by an intermediate host, which is usually some one of the herbivorous animals such as sheep, cattle, hogs, or rabbits, but may also be man. After ingestion by an intermediate host, the shell of the egg is digested and the onchosphere escapes and burrows into the intestinal wall to reach the blood stream. It is usually carried by the blood to the liver, but may pass to the lungs, brain, kidneys or other organs, or to the muscles.

In the liver, or other tissues, the onchosphere develops to form the hydatid, or echinococcus, cyst. A vesicle is first formed which by gradual enlargement over a period of months or years develops into a cyst. The cyst may be several inches in diameter. The cyst wall consists of an outer layer of laminated cuticle and an inner parenchymatous or germinal layer. The cyst is filled with fluid. Large numbers of brood capsules containing the scolices are formed from the parenchymatous layer of the cyst wall.

The hydatid cyst may be unilocular or multilocular. Daughter and granddaughter cysts may be formed from the germinal layer of the wall of the mother cyst. These cysts may be disseminated to other tissues. The multilocular cysts may be caused by the larval form of a subspecies of *T. echinococcus.*

Prevalence and importance. Infestation of man with the larval form of *T. echinococcus* occurs where there is close association between man and dogs. It is, therefore, most prevalent in stock raising countries. The incidence is the highest in Iceland, but hydatid disease is of fairly frequent occurrence in Australia, New Zealand, South Africa and Central Europe. Most of the human cases found in the United States are imported. Infestation of dogs and herbivora occurs in the United States, as hydatid disease is occasionally found in hogs by meat inspectors.

Clinically, hydatid disease is a serious condition and surgery is the only treatment.

Transmission. The eggs are transmitted to the intermediate hosts from the feces of the dog. They may be transmitted to man by hands which have been contaminated by contact with the dog host or more indirectly by articles contaminated with the feces of the dog. The eggs are transmitted to herbivorous animals on grass and other herbage.

Carnivora are infested by the ingestion of flesh containing the larval forms (hydatid cysts) of the worm, such as the offal of the infested hogs, cattle or sheep. In Australia, dogs are infested by eating infested rabbits.

Control measures. Primarily, the control of hydatid disease in man is a question of preventing infestation of dogs. Dogs should be kept away from slaughterhouses or other places where they might gain access to the offal from infested animals and suitable measures should be taken to dispose of the offal of all ani-

mals. Direct transmission from dog to man is prevented by avoiding fondling or handling of dogs which might be infested.

Enterobius vermicularis (*Oxyuris vermicularis, pin worm, seat worm, thread worm*). *Enterobius vermicularis,* or pin worm, is a common parasite in the intestinal tract of man. The adult male worm is about 4 millimeters in length. The adult female is much larger than the male, measuring about 10 millimeters in length. The gravid female worms pass from the large intestine into the rectum and are excreted with the feces or migrate from the rectum onto the skin of the perianal region. Eggs containing embryos are deposited on the perineum and on the skin around the anus. When ingested the ova hatch in the small intestine, where the larval forms moult and mature. The adult worms migrate to the large intestine.

The ova are found in material obtained by scraping or swabbing the perianal skin or the rectum. The gravid female and occasionally the eggs may be found in the feces.

Infestation with *Enterobius vermicularis* is manifested by pruritus ani due to the irritation caused by the presence of the worms and ova. The itching is usually more severe at night. Eosinophilia is fairly common, and children may present nervous symptoms of various kinds.

Infestation with pin worms is prevented by personal hygiene which precludes the transfer of fecal material on the hands, or on things handled in common. No person infested with *Enterobius vermicularis* should be allowed to handle the food of others. In the treatment of a case, care must be taken to avoid auto-infestation. Measures to insure scrupulous cleanliness of the hands and body should be enforced. The sleeping garments and bed sheets used by the patient should be changed daily.

Ascaris lumbricoides (*Round worm, eel worm*). *Ascaris lumbricoides* is an intestinal parasite of man. The adult female is much larger than the male, measuring about 30 centimeters in length and about 5 millimeters in diameter. The male is about 20 centimeters long and about 3 millimeters in diameter. The female deposits an enormous number of eggs in the intestine which are discharged in the feces. The ova as they leave the body in the feces are unsegmented and undeveloped, and are not infective for man at this time. Outside the body, given favorable conditions with regard to warmth and moisture, the embryo develops in the egg in from two to three weeks. The embryonated eggs are infective when ingested.

The eggs of *A. lumbricoides* are highly resistant to freezing, drying and disinfectants, and will remain viable under adverse environmental conditions for long periods of time.

The ripe eggs are transferred to man on food contaminated with soil or other material containing the eggs, by dirt and soil on the hands, and possibly in water. The ingested ova hatch in the small intestine and the larvae pass through the wall of the intestine into the portal circulation. They are carried by the blood stream through the liver and heart to the lungs where they undergo further development in the alveoli. Eventually the larvae migrate through the bronchi and trachea to the esophagus and then through the stomach to the small intestine. In the intestine they moult and develop into adults.

Usually, infestation with *A. lumbricoides* produces no clinical symptoms and the diagnosis is made by finding the ova in the feces. Occasionally, a variety of clinical manifestations may be caused by the passage of the larvae from the intestine into other organs of the body. The adult worm may wander from the intestine into the bile ducts, the appendix, the peritoneal cavity or elsewhere, and cause pathological conditions. Some individuals may present a toxemia due to the absorption of toxic products produced by the worms in the intestine. There is usually a low grade eosinophilia. In children, ascariasis may be accompanied by nervous manifestations.

Hogs are frequently infested with a worm which is morphologically indistinguishable from *A. lumbricoides*, but there is considerable evidence showing that the parasite of swine is not epidemiologically identical with *A. lumbricoides* of man.

The distribution of *A. lumbricoides* is world wide, but because of environmental conditions, ascariasis is more prevalent in the warmer climates.

The prevention of ascariasis is primarily dependent upon the sanitary disposal of feces. Children are frequently infested as the result of playing in contaminated soil and dust. Vegetables that have been fertilized with human feces may carry the ova of *A. lumbricoides*. Among troops, infestation with *A. lumbricoides* is prevented by the proper disposal of human wastes, thorough washing of vegetables that are to be eaten raw, and good personal hygiene.

CHAPTER VI.

WATER PURIFICATION

The Quartermaster Corps is responsible for the construction, maintenance and operation of water purification plants and distributing systems and for the quantity and quality of the water supply at all stations, camps and installations in time of peace, and in the Zone of the Interior in war. The Corps of Engineers is responsible for the supply of water in the Theater of Operations to divisions (and smaller units where practicable) and higher mobile units, and to fixed installations.

Sanitary control by the Medical Department. The Medical Department being responsible for the health of all troops, is charged with the responsibility for making surveys, inspections, and examinations of water supplies, and such recommendations as may be necessary to protect the health of the troops. The Medical Department cooperates with the Quartermaster Corps or the Corps of Engineers, as the case may be, in all phases of water purification work.

The scope of the sanitary control exercised by the Medical Department includes the following measures:

a. Sanitary surveys of the source or sources of proposed water supplies, or extensions of existing supplies, for actual or potential sources of contamination, and for adequacy of supply in so far as quantity will affect the health of the troops.

b. The study of plans for proposed water purification works and other appliances or installations to be utilized in the treatment of water, with particular reference to sanitary features, prior to their final adoption.

c. Sanitary surveys and inspections of existing water

supply systems, including sources, installations, appliances, and procedures utilized in the treatment of the water, and the distributing system.

d. The bacteriological and chemical analysis of water as delivered to the troops.

e. The technical supervision of the procurement and purification of the water supply where emergency measures are necessary, such as the use of the water sterilizing bag (Lyster bag).

QUALITY OF WATER

Contaminated water is water which contains disease producing organisms. Water may contain impurities other than disease producing organisms, or possess qualities or properties which render it deleterious to health, unpalatable or otherwise unsuitable for domestic use.

Contamination. Contamination consists of pathogenic organisms, and in water purification procedures only those organisms which cause intestinal diseases are considered. The causal agents of intestinal diseases are carried into the water by human excreta and, as it is impracticable to detect and isolate such organisms from water, any water containing human excreta is regarded as being contaminated.

The sources of contamination are the sources of human excreta, and human excreta may reach a water supply in any one of a number of ways. Raw sewage may be discharged from a sewer into a water supply; the effluent from sewage treatment works may carry contamination into the water; defective or improperly placed drains or sewers may permit the escape of sewage and subsequent contamination of the water; the contents of privies, latrines or cesspools may seep through the soil or pass through fissures or cracks in the underlying rock stratum into a water supply, or the runoff of storm water may carry with it human excreta from flooded privies, latrines or cesspools or from deposits on the ground.

While water contaminated with human excreta does not necessarily contain pathogenic organisms, nevertheless, such water is potentially dangerous to health as it may at any time become infected with pathogenic organisms. Consequently,

any water contaminated with human excreta should be regarded as dangerous to health.

Physical and chemical properties detrimental to health. The presence of excessive turbidity, disagreeable tastes and odors, color or hardness may indirectly affect health through interference with purification measures, or by rendering the water so objectionable that water discipline will be difficult to maintain and the troops will drink water from unauthorized and contaminated sources. Waters containing excessive quantities of sodium or magnesium sulphate, the so-called alkali waters, are objectionable and may be non-potable. They produce deleterious effects on the health of the consumer by causing catharsis and diarrhea.

Turbidity. Turbidity is due to suspended material in the water, usually silt, sand and clay, and organic matter, which give it a turbid or muddy appearance. The suspended material is derived from the soil through erosion by flowing water, and consequently, surface waters are usually turbid, while ground waters frequently have low turbidity or are clear.

The amount of turbidity in the water is expressed as parts per million, that is, the number of parts of turbidity by weight in one million parts of water. For example, if one part by weight of powdered silica is mixed with one million parts of distilled water, the resulting suspension has a turbidity of one part per million.

The Hellige turbidimeter can be used by plant operators to determine the turbidity of water rapidly and accurately (Fig. No. 21). The turbidity is measured by comparing the amount of light reflected by particles in the water with that reflected from illuminated glass disks.

Turbidity measurements may be made according to procedures specified in Standard Methods of Water Analysis, 8th Edition, 1936, American Public Health Association, which are as follows:

"Turbidity measurements are based on the depth of suspension required for the image of the flame of a standard candle to disappear when observed through the suspension. The standard instrument for making such measurements shall be the Jackson candle turbidimeter, which consists of a graduated glass tube, a standard candle, and a support for the candle and tube. The glass tube and the candle shall be supported in a vertical position so that the center line of the tube passes through the center line of the candle, the top support for the candle being 7.6 cm. (3 inches) below the bottom of the tube.

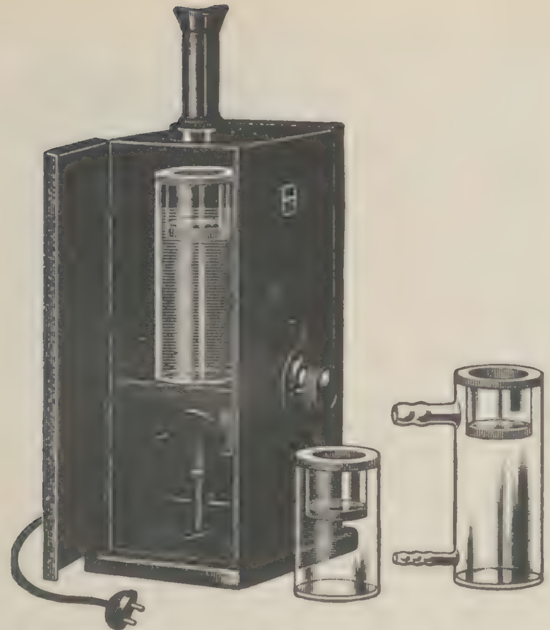


FIG. No. 21. Hellige turbidimeter for determining small quantities of turbidity in water. (Courtesy of Eimer and Amend, New York, N. Y.).

The glass tube shall be graduated, preferably to read direct in turbidities, and shall have a flat polished bottom. Most of the tube should be enclosed in a metal or other suitable case when observations are being made. The candle support shall have a spring or other device so as to keep the top of the candle pressed against the top of the support. The candle shall be made of beeswax and spermaceti gauged to burn within the limits of 114 to 126 grains per hour.

"To insure uniform results, it is desirable that the flame be kept as near constant size and constant distance below the glass tube as is possible. This will require frequent trimming of the charred portion of the candle string and frequent observations to see that the candle is pushed to the top of its support. Each time before lighting the candle remove such portion of the charred part of the string as is very easily broken off with the fingers. Do not keep the candle lighted for more than a few minutes at a time, for the flame has a tendency to increase in size.

"The observation is made by pouring the suspension into the glass tube until the image of the candle flame just disappears from view. Pour very slowly when the candle flame becomes only faintly visible. After the image has disappeared the removal of one per cent of the suspension from the tube should make it again visible. Care should be taken to keep the glass tube clean on both the inside and the outside. The accumulation of soot or moisture on the lower side of the glass bottom of the tube may interfere with the accuracy of the results.

"The figures in Table I give the turbidities for the depth at which the image of the candle flame just disappears.

"Observations should be made in a darkened room or with a black cloth over the head. It is allowable to substitute for the standard candle other forms of light, but the instrument must be calibrated to give turbidity readings that correspond with the standard candle.

TABLE I.

Graduation of Candle Turbidimeter.

Depth of liquid (cm.)	Turbidity.	Depth of liquid. (cm.)	Turbidity.
2.3	1000	11.4	190
2.6	900	12.0	180
2.9	800	12.7	170
3.2	700	13.5	160
3.5	650	14.4	150
3.8	600	15.4	140
4.1	550	16.6	130
4.5	500	18.0	120
4.9	450	19.6	110
5.5	400	21.5	100
5.6	390	22.6	95
5.8	380	23.8	90
5.9	370	25.1	85
6.1	360	26.5	80
6.3	350	28.1	75
6.4	340	29.8	70
6.6	330	31.8	65
6.8	320	34.1	60
7.0	310	36.7	55
7.3	300	39.8	50
7.5	290	43.5	45
7.8	280	48.1	40
8.1	270	54.0	35
8.4	260	61.8	30
8.7	250	72.9	25
9.1	240		
9.5	230		
9.9	220		
10.3	210		
10.8	200		

"Samples having a turbidity above 1000 parts per million shall be diluted with one or more equal amounts of turbidity-free water, until the resultant turbidity falls below 1000 parts per million. The turbidity of the original sample should be computed from the reading made on the dilute sample. For example, if the reading on the dilute sample is 500 and the amount of the original sample in the dilute sample is 1 part in 6, the turbidity of the original sample is 3000."

A.

B.

FIG. No. 22. A—The Baylis turbidimeter for determining turbidity of water below 2.0 parts per million. (Courtesy of the Eimer and Amend Co., New York, N.Y.). B—Jackson candle turbidimeter for determining turbidity of water of more than 25.0 parts per million. (Courtesy of the Central Scientific Co., Chicago, Ill.).

Turbidity of less than 25 parts per million cannot be measured with the candle turbidimeter, and other methods must be used where the water contains only a small amount of turbidity.

In the operation of water purification works where frequent determinations of turbidity are required, measurements which are sufficiently accurate for practical working conditions can be made by comparison with standard suspensions in bottles. The measurements made by this method fall between 5 and 100 p.p.m. If the sample being examined has a turbidity of more than 100 p.p.m., it must be diluted with clear water so that the turbidity is less than 100 p.p.m.

The method of preparing the standard suspensions and measuring the turbidity of the sample is described in Standard Methods of Water Analysis, 8th Edition, 1936, as follows:

PREPARATION OF STANDARDS

"Add about 5 g. of fullers' earth to 1 liter of distilled water, thoroughly agitate intermittently for an hour and then allow to stand 24 hours. Withdraw the supernatant without disturbing the sediment in the bottom and test the turbidity with the candle turbidimeter. Take successive portions of the suspension and dilute with distilled water until the mixtures resulting correspond to the depth of liquid reading

of the various turbidity standards desired in the 5-100 range, using the candle turbidimeter for making the readings.

"If fullers' earth does not produce a suspension, the color of which is reasonably similar to the suspended matter in the water under examination, suspended matter or bottom sediments from a stream may be acid treated to remove soluble constituents, washed by decantation and adjusted as above directed.

"The standards, when prepared, shall be placed in clean resistant glass bottles of 1 liter capacity or greater. Enough free space at the top of the bottle shall be left to allow adequate agitation when readings are being made.

"The standards shall be made fresh at least every month and shall be kept tightly stoppered.

"In order to prevent bacterial or algae growths from developing, a small amount of mercuric chloride may be added to the standards.

PROCEDURE

"The sample, contained in a bottle of the same type as the standards, and the standards shall be well shaken. The comparison shall be made by viewing the sample and the standards sidewise, looking through both at some object and noting the distinctness with which it can be seen. The turbidity of the sample shall be recorded as that of the standard bottle which produced the visual effect most closely approximating that of the sample.

"Readings will be facilitated if a series of black ruled lines on white paper be the object viewed, and further, if the light, preferably electric, illuminates both sample and standards from above while the comparison is being made, with no direct rays from the light reaching the eye."

In the field, turbidity may be determined with the United States Geological Survey turbidity rod (Fig. No. 23). The rod consists of a metal portion and a tape portion, which when fastened to a stick, constitute a "rod." A one-inch platinum wire one millimeter in diameter projects at right angles from one end of the rod. The wire end of the rod is submerged vertically in the water being tested while the observer looks down at the wire with the eye level with the 1.2 meter mark on the tape. The rod is pushed down into the water until the turbidity obscures the wire from view of the observer. The depth below the surface at which the wire disappears is measured by the graduated scale on the rod in terms of parts per million of turbidity.

Apparatus of greater precision is required to measure accurately turbidities of less than 5 p.p.m.

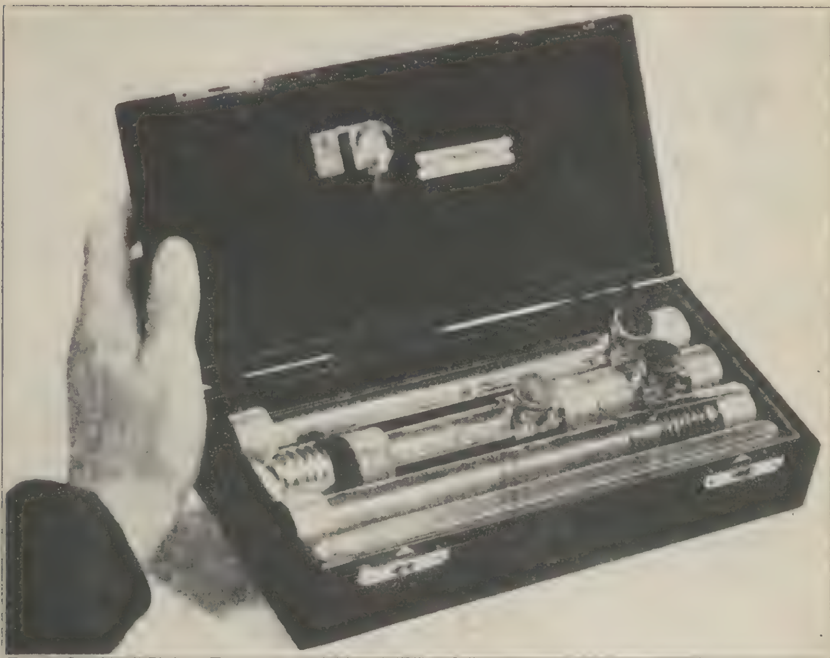


FIG. No. 23. Water color and turbidity testing set. U. S. Geological Survey Standard. (Courtesy of the Precision Scientific Co., Chicago, Illinois.).

A turbidity of 5 parts per million is barely noticeable in an ordinary drinking glass; from 10 to 15 parts per million will render the water objectionable; 100 parts gives it a decidedly muddy appearance, while 500 to 1000 parts renders it practically opaque.

Color. True color in water is due to the presence of coloring matter in solution. Apparent color is due to colored matter which is in suspension in the water and which can be removed by sedimentation or filtration.

True color is usually caused by extracts of decomposing vegetable matter. For example, the dark color of swamp water is a true color and is due to the tannates and gallates extracted from decaying leaves and bark.

The amount of color in water is expressed as parts per million and may be determined by comparing the color of the water with that of a standard solution. The stock standard solution is made as follows:

Dissolve 1.245 grams of potassium chloroplatinate, containing 0.5 gram of platinum, and 1 gram of crystallized cobaltous chloride, containing about 0.25 gram of cobalt, in water with 100 c.c. of concentrated hydrochloric acid, and dilute to one liter with distilled water.

The stock standard solution has a color of 500 parts per million. Dilute standards having 5, 10, 15, etc. parts per million of color are made by diluting 0.5, 1, 1.5, etc. of the stock standard solution to 50 c.c. with distilled water. The diluted standard solutions are placed in Nessler tubes and the color of the standard solutions is compared with the color of equal quantities of the sample being tested. If the sample has more than 70 parts per million of color, it should be diluted with distilled water. (Standard Methods of Water Analysis.)

In field work, the color of water may be determined by comparing the color of water to be tested with that of standardized colored glass discs. The discs and the technique used by the United States Geological Survey yield results which are approximately the same as those obtained by comparison with standard solutions (*supra*).

Water should contain not more than five parts per million of color and ten parts per million will render the water unsightly. Ordinarily, the larger part of the color can be removed from water by coagulation and filtration (page 242).

Hardness. The hardness of water is due to the presence of the soluble bicarbonates, sulphates, chlorides and nitrates of calcium and magnesium. These chemicals form deposits in boilers and pipes of steam-heating and hot water plants and appliances, decreasing their efficiency and necessitating more frequent cleaning. They also form insoluble salts with soap and impair the value of the water for domestic or laundry purposes (page 323).

SOURCES AND CHARACTERISTICS OF WATER SUPPLIES

The remote source of all water is the rain or snow which falls on the earth. The immediate sources of water used for water supplies are rain water, which has been collected in cisterns or similar containers, surface water, and ground water.

Rain water. Rain water is similar to distilled water and if properly collected and stored, it is free from contamination. As it contains relatively small quantities of dissolved chemicals, it is soft and well adapted for domestic uses. Rain

water, as such, is rarely used by military forces as a water supply.

Surface water. Surface water is water lying on the surface of the ground in contact with the atmosphere. It occurs in the form of streams, lakes, ponds and impounded reservoirs and is derived from rain or snow water which has not been absorbed into the earth and ground water which has risen to the surface from underground sources.

In many instances, surface water constitutes the only available source of water supply for a military station, a camp or for marching troops. Generally, a surface water supply is adequate and readily accessible but has the disadvantage of being subject to contamination.

Characteristics of surface water. A surface water supply is usually obtained from a stream or a stream fed lake, pond or impounded reservoir. Streams which drain an inhabited water shed serve as sewers which receive, directly or indirectly, and carry away a greater or less proportion of human wastes produced by the inhabitants. Consequently, for practical purposes, any water flowing through an inhabited country should be considered as being contaminated with human excreta. As military stations and camps are always located, and military forces always operate, in inhabited portions of the country any surface water which may be used as a water supply for troops should be regarded as contaminated.

Surface water is usually turbid and may contain substances which cause disagreeable tastes or odors. As a rule, surface water is comparatively soft. Hard surface water occurs where the surface water is mixed with ground water containing dissolved mineral substances which cause hardness.

Measurement of the flow of streams. It may be desirable at times to measure the rate of flow of small streams to determine if a given stream will supply a sufficient quantity of water. Ordinarily, only a rough estimate is required. Under suitable conditions, the flow can be measured with a weir. In other instances, estimations based on the velocity-area method will suffice.

The flow of water in ditches, or in small narrow streams having steep banks, may be estimated by the use of an improvised weir as shown in Figure No. 24. The weir is so placed that it forms a dam and all the water must flow through

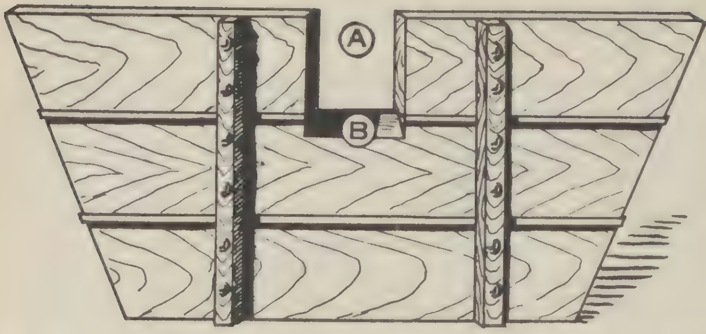


FIG. No. 24. Improvised weir for measuring the flow of small streams.
A—Central spillway opening. B—Beveled crest.

a central spillway opening. The crest of the weir, that is, the bottom of the opening, is beveled so that it is not more than one-fourth inch thick. The vertical side of the bevel is placed upstream.

The following weir table gives the flow in gallons per minute over a 12-inch weir. These quantities are rough estimates only, as certain corrections must be made in order to obtain absolute accuracy. The results are, however, sufficiently accurate for field work.

WEIR TABLE

Flow in Gallons per Minute Over a Weir 12 inches Wide.

Depth in inches	Gallons per minute	Depth in inches	Gallons per minute	Depth in inches	Gallons per minute
1	36	4¾	375	8½	900
1¼	50	5	405	8¾	939
1½	66	5¼	436	9	978
1¾	84	5½	468	9¼	1,020
2	102	5¾	500	9½	1,062
2¼	122	6	533	9¾	1,104
2½	143	6¼	567	10	1,147
2¾	165	6½	601	10¼	1,190
3	188	6¾	636	10½	1,234
3¼	212	7	672	10¾	1,279
3½	237	7¼	708	11	1,323
3¾	263	7½	745	11¼	1,369
4	290	7¾	783	11½	1,414
4¼	317	8	821	11¾	1,461
4½	346	8¼	860	12	1,508

The velocity-area method determines the capacity of a selected section of the stream bed and the time required for the

stream to fill the section, and from these two factors the rate of flow is calculated. The dimensions of a section of the stream of fairly uniform width and depth are determined by measuring. The velocity of the flow through the measured section is ascertained by observing the time required for the current to carry a surface float from the upper to the lower boundary of the section. The mean velocity of the stream is about four-fifths of the surface velocity. The rate of flow in cubic feet per second would be:

$$\frac{D \times W \times L}{V}$$

Where:- D=the average depth of the water in the measured section.
W=the average width of the measured section.
L=the length of the measured section.
V=the mean velocity expressed as the number of seconds required for the measured section to empty.

The rate of flow in gallons per second would be the number of cubic feet per second multiplied by the number of gallons in a cubic foot, which is 7.48. For example, given a section of a stream which has an average width of four feet, an average depth of six inches and is 25 feet long, through which it requires 20 seconds for the current to carry a surface float. As the mean velocity is four-fifths of the surface velocity, 25 seconds would be required to empty the 25 foot section, or in other words V in this problem is 25.

$$\text{Rate of flow} = \frac{4 \times 0.5 \times 25}{V}$$

$$= \frac{4 \times 0.5 \times 25}{25}$$

$$= \frac{50}{25}$$

= 2 cubic feet per second.
= 2 × 7.48 or 14.96 gallons per second.

Ground water. Ground water is the water that lies below the surface of the ground and is not in contact with the atmosphere. As the water which has fallen, or is lying upon the surface of the ground seeps downward into the earth to become ground water, it eventually reaches a layer of material which becomes saturated with water. In this saturated zone the water is under hydrostatic pressure. Above the saturation zone is another zone in which the water is held in the interstices of the soil by capillary attraction and is not under hydrostatic pressure. The latter zone is known as the capillary

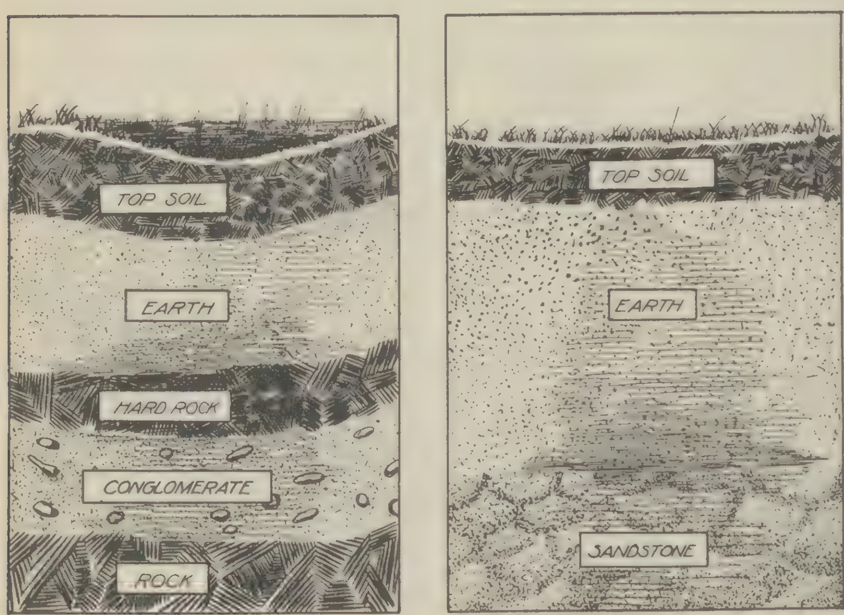


FIG. No. 25. Ground water table and strata that govern flow of ground water (Schematic).

fringe, while the upper surface of the zone of saturation is called the ground water table. Only ground water, which is under hydrostatic pressure and flows at or below the ground water table, can be recovered from wells or springs (Fig. No. 25).

When during its downward passage the water in the saturation zone is blocked by an impervious stratum of rock or clay, it flows along the impervious stratum until it reaches the surface of the earth as a stream or spring, or until it passes

through the first impervious stratum to flow between other and deeper strata.

Except in limestone formations, ground water does not occur as underground lakes, ponds or streams, but as a body of water which flows by seepage through the porous material in which it is contained, or through faults and cleavage lines in the rock strata. In limestone, the solvent action of the water, and consequent erosion, may produce caverns and tunnels in which large bodies of water are retained or through which underground streams flow by gravity. Under all other conditions, the rate of flow is governed by the nature of the pervious stratum, by the hydrostatic pressure and by the slope of the underlying impervious strata and varies from a very slow movement up to 40 or 50 feet per day. The direction of the flow is controlled by the slope of the impervious strata which may or may not correspond to the contours of the ground surface. Usually, but not always, the slope of the uppermost impervious stratum follows approximately the contours of the overlying earth, except that it is more nearly level than the surface of the ground. The deeper strata may be inclined at angles which bear no relation to the topography of the surface of the ground.

Ground water is recovered through wells or springs from formations consisting of sandstone, sand and gravel, the channels and caverns in limestone, drift (a mixture of clay, sand, gravel and boulders), or from the joints, faults and cleavage planes of the harder rocks.

Characteristics of ground water. All ground water is originally surface water and has at that time the characteristics of surface water (page 223). As it sinks into the earth to become ground water, the filtering action of the soil tends to remove the suspended organic material, including bacteria, while certain of the minerals in the earth are dissolved and carried away in solution by the water. Consequently ground water contains less suspended organic matter, fewer bacteria and greater amounts of mineral matter than surface water. The degree to which the suspended organic matter is removed by filtration through the soil, and the quantity and the nature of the dissolved minerals in a given supply of ground water, depend upon the distance which the water has traveled through

the ground and the character of the soil through which it has passed.

The ground water lying above the uppermost impervious stratum at any given point is derived in part from the surface of the adjacent terrain. Before it enters the ground it is exposed to the same sources of contamination as surface water and the short distance which it flows through the earth does not permit complete removal of the suspended organic matter by filtration. Consequently, this type of ground water is frequently contaminated with pathogenic organisms, but does not as a rule contain any considerable quantity of dissolved minerals. This is the layer of ground water that is tapped by a shallow well.

The water lying below the first impervious stratum at any selected place is derived from more remote sources and is protected from immediate sources of contamination by the overlying impervious stratum. The comparatively long distance which such water passes through the earth serves to filter out the suspended organic matter and to render it potable from a bacteriological and turbidity viewpoint. It may, however, contain relatively large quantities of dissolved minerals. This is the ground water that is recovered by means of deep wells.

WELLS

Wells are usually classified as shallow and deep according to their relation to the uppermost impervious stratum. A shallow well is one which does not extend through the first impervious stratum of the earth. Such a well is apt to yield water which is derived from the surface of the nearby terrain, some of which has not passed through the soil for a sufficient distance to effect purification by filtration.

A deep well extends down into a water-bearing stratum below the uppermost impervious stratum. Consequently, if the water from ground above the uppermost impervious stratum is excluded from the well, the water recovered from a deep well is limited to that flowing below the impervious stratum. This water has come from comparatively remote surface sources and the contamination which it might have derived from these remote sources has been removed by filtra-

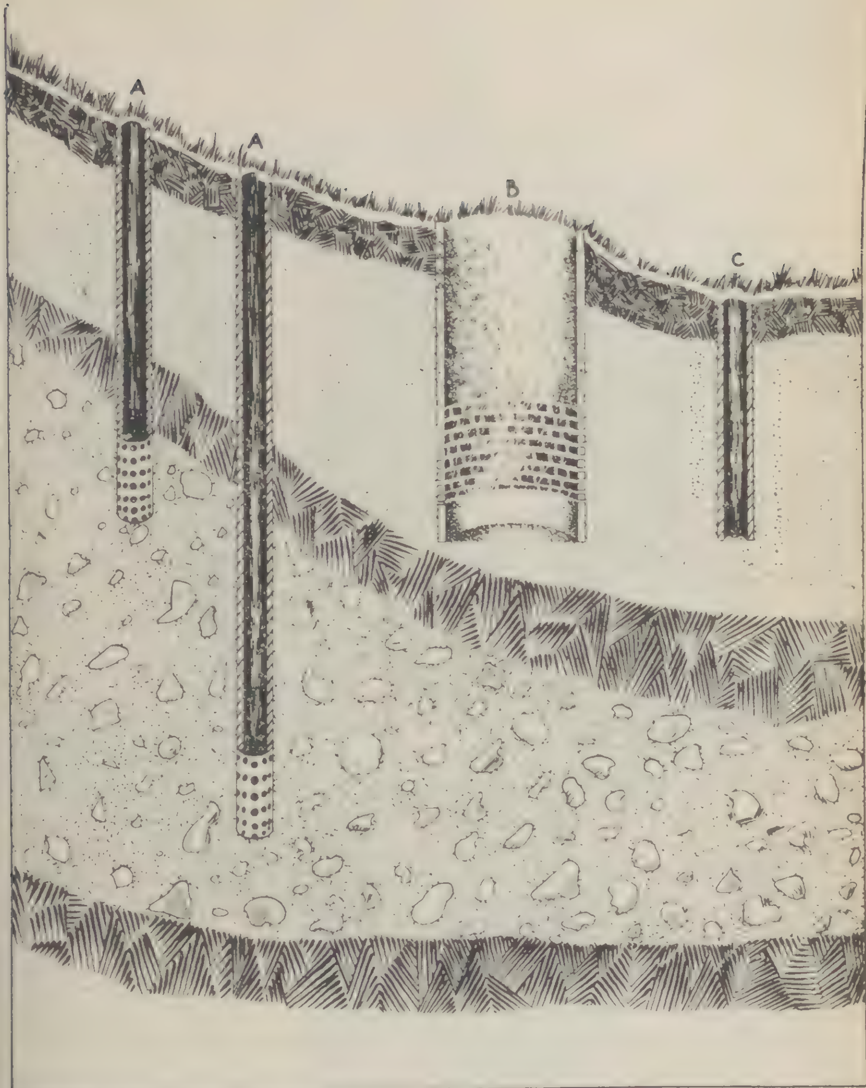


FIG. No. 26. Deep and shallow wells (Schematic). A—Deep wells. These are drilled wells extending through an impervious stratum. B—Shallow, dug well. C—Shallow driven, bored or drilled well.

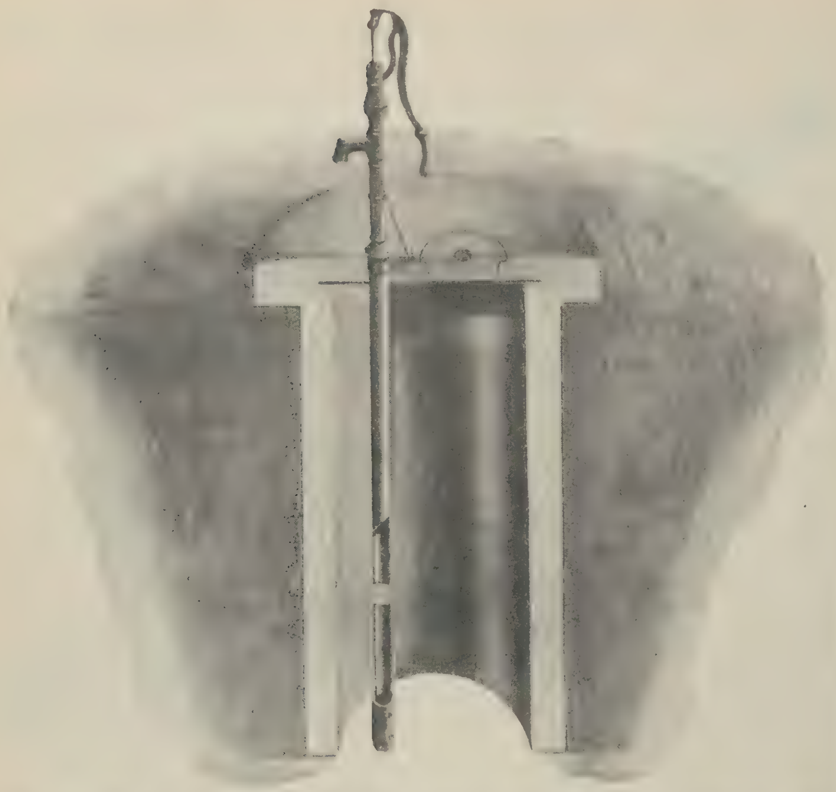


FIG. No. 27. A protected dug well (Schematic). Concrete platform with manhole. Concrete casing.

tion through the earth. The overlying impervious stratum serves to protect the water flowing into a deep well from sources of contamination adjacent to the well.

The actual depth of either a deep or shallow well, under this classification, may vary within wide limits depending upon the depth of the first impervious stratum below the surface of the ground.

Wells may be classified according to the method used in their construction as dug, driven, drilled or bored wells. The dug, driven or bored wells are essentially shallow wells in that they do not penetrate an impervious stratum. The drilled well may or may not pass through an impervious stratum and therefore may be either deep or shallow (Fig. No. 26).

Wells may also be classified as artesian and non-artesian. An artesian well is one in which the water in the well rises

above the level of the water in the surrounding earth. An artesian well may or may not be a flowing well. In this classification, the non-artesian wells are sometimes arbitrarily divided into shallow and deep types according to their depth, a well less than 100 feet in depth being classed as a shallow well and one that is more than 100 feet deep as a deep well.

Dug wells. Dug wells are from three to six feet in diameter and usually not more than 25 feet in depth. They should be lined for at least eight feet below the surface with a casing which is as nearly watertight as practicable. The casing may be made of concrete, timbers, corrugated iron or of

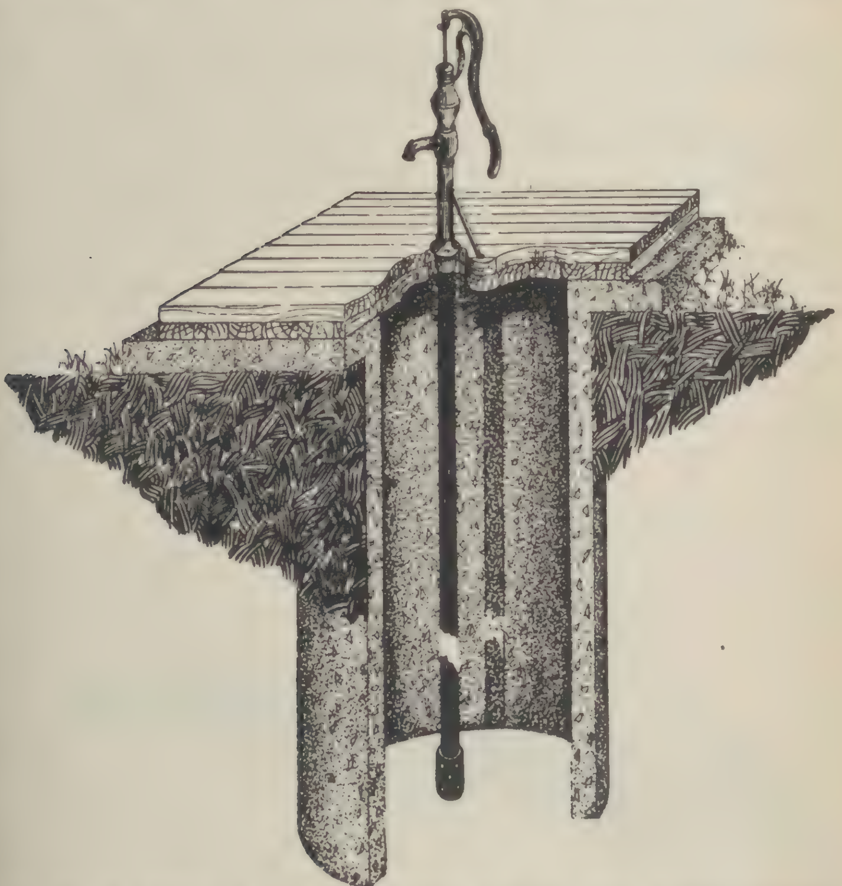


FIG. No. 28. Method of protecting shallow dug well from surface contamination (Schematic). Wooden platform with concrete base. Concrete casing.

bricks laid in cement mortar. Where practicable, concrete should be used. The entrance of surface water into the mouth of the well should be prevented by extending the casing from 12 to 24 inches above the surface of the ground. The well opening should be protected by a concrete, brick or wooden platform so constructed that all drainage is away from the well. If the platform is made of brick, the bricks should be laid in cement mortar, if of wood, the boards should fit tightly and be placed in two layers at right angles to each other. The pump may be located at one side of the well. If it is placed over the well, it should be so installed that there will be no leakage of water through the platform (Figures No. 28 and 29).

Driven wells. A driven well is constructed by driving an iron pipe into the ground with a driving machine or by hand. A driven well can be constructed only in sand, loose gravel or clay soils where boulders or rock will not be encountered. The pipes are usually from one to four inches in diameter. The lower end consists of a perforated, or strainer, section from two to five feet in length through which the water enters the pipe.

A driven well may be constructed by washing down with water under pressure. A small pipe is placed inside the outer

FIG. No. 29. Method of protecting drilled, driven, or bored wells from surface contamination (Schematic).

and larger pipe to carry a stream of water which forces the dirt upward and out through the larger pipe. Where conditions are suitable, the weight of the outer pipe, or casing, will cause it to sink downward as the dirt is washed away.

To prevent contamination of the water in the well by surface water, the pipe should have tight joints and should extend above the surface of the ground (Fig. No. 30).

Bored wells. Bored wells are made with hand or power driven augers. They are usually from four to eight inches in diameter and not more than 100 feet in depth, although the diameter may vary from two inches to three feet and the depth may be as much as 300 feet. The casing consists of short sections of galvanized or cast iron piping. It should extend above the surface of the ground and the joints should be water tight.

Bored wells can be put down through loose material and the harder clay formations but cannot be constructed in soils containing large boulders or rock strata.

Drilled wells. Drilled wells are commonly from two to twelve inches in diameter and can be sunk to comparatively great depths. The appliances used in making a deep well consist of power driven drills of various kinds which can penetrate hard rock strata. The casing usually consists of steel or wrought iron piping which, in order to protect the water in the well from surface drainage, must be water tight and extend above the surface of the ground or project through a water tight pump house floor.

Yield of wells. The rate of flow of water into a well, or the yield of the well, may be roughly determined by reducing the depth of the water a measured distance, noting the time required for the water to reach again a given level, which should be below the original level, and calculating the capacity in gallons of the space between the two levels.

The quantity of water expressed as cubic feet in any given depth of a circular well is determined by multiplying the square of the diameter of the well in feet by 0.7854 and multiplying the figure thus obtained by the depth of the measured section in feet. The content in gallons is determined by multiplying the number of cubic feet by 7.48, which is the number of gallons in one cubic foot. For example, given a circular well three feet in diameter in which the normal water level has

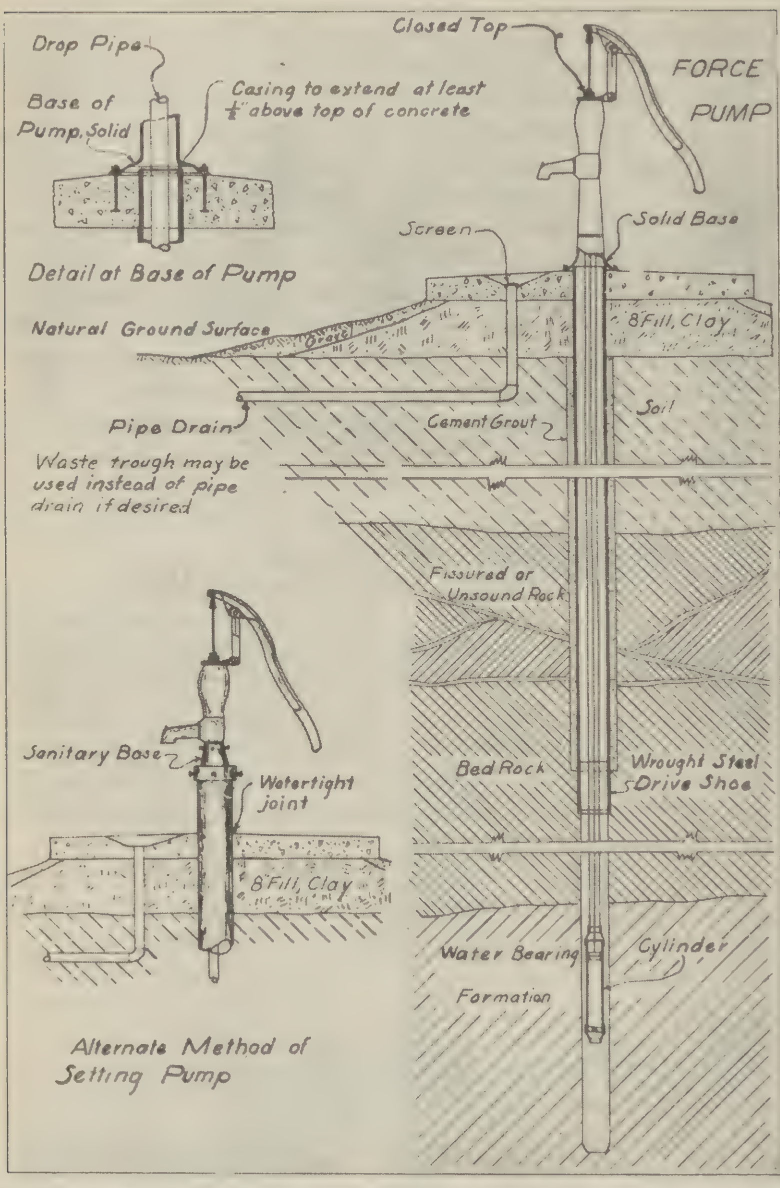


FIG. No. 30. Drilled well passing through an impervious stratum, and method of installing pump. (Courtesy of the Department of Health, Commonwealth of Virginia, Richmond, Virginia).

been reduced two feet by pumping, and assuming that the water rises one foot in 30 minutes after the pumping has ceased, the yield is computed as follows:

$$
\begin{aligned}
\text{Yield} &= 0.7854 \times 3^2 \times 1 \times 7.48 \\
&= 0.7854 \times 9 \times 1 \times 7.48 \\
&= 7.07 \times 1 \times 7.48 \\
&= 7.07 \times 7.48 \\
&= 51.9 \text{ gallons in 30 minutes.}
\end{aligned}
$$

If the yield is 51.9 gallons in 30 minutes, the yield for 24 hours will be 48 times 51.9, or 2491 gallons.

If, under the conditions of actual use, the pumping rate is greater than during the test, the yield will be somewhat more as the water will be drawn from a larger area. The depth of the water below the normal water line, the extent and nature of the water bearing stratum, and the rate of pumping are factors which must be considered in making an accurate estimate of the yield, but can be ignored in making practical field tests.

Contamination of well water. Bacterial contamination may reach the water in a well in one of two ways. First, it may be carried by the water as it passes down through the ground from sources at or near the surface and, second, it may enter the mouth of the well in the surface water or other infected material and pass directly into the water in the well.

In the case of shallow wells, contamination derived from surface sources in the immediate vicinity will be carried to the well, if the flow of ground water is towards the well, before it is removed by filtration though the soil. Contaminated water may enter a driven or bored well, or a drilled well which terminates above the upper impervious stratum, through the strainer or the lower end of the pipe or through cracks or loose joints in the casing. A dug well may receive contaminated water at the lower end or through any part of the well which is not water tight.

The water in a deep well is usually free from bacteriological contamination, provided contamination does not enter through defects in the casing above the uppermost impervious stratum or through the mouth of the well. The sources of contamination are usually remote and the water is purified by passage through the earth. The exceptions are deep wells which penetrate into a limestone formation and tap a body of

free flowing water in a fissure or channel. This water may have been subject to contamination at a distance from the well and may have passed underground for the greater part of that distance in an open channel. It has not, as in the case of other ground water, been filtered through the soil and is, therefore, essentially surface water and tends to retain much of the original contamination.

Detection of contamination. The detection of probable or actual bacterial contamination of ground water is determined, as in the case of all water supplies, by surveys and inspection on the ground and by laboratory tests of the water (page 358). A rise in the water level in a well, or an increase in the turbidity of the water after a storm is evidence that surface water is flowing into the well.

Certain chemical compounds which can be detected in small quantities in water by their taste, odor or color, may be used to determine if surface drainage from a ditch, stream, pond, cesspool, or privy, is reaching the water in a well. A small quantity of kerosene may be applied to the suspected source of contamination and if there is drainage from that source into the well, the kerosene can be detected by taste and odor in the well water in dilutions as high as one part per million. Fluorescin may be used as a test substance in the form of a solution of one gram in about a liter of water rendered alkaline with sodium hydroxide or ammonia. When the solution of fluorescin is applied to a suspected source of contamination and is carried into the well, it can be detected in the well water by its fluorescent green color in dilutions as high as 0.7 parts per million.

Purification of well water. Well water, as a rule, is clear and does not require treatment for the removal of suspended sediment. However, all water from shallow wells and from limestone formations should be regarded as surface water and therefore contaminated or subject to contamination with human excreta, and should be chlorinated before being issued to troops. Water from a deep well, except that obtained from limestone formation, may be considered safe without treatment provided that the top of the well is adequately protected, the casing is not defective, and the bacteriological examinations are negative. As a general rule, all well water should be chlorinated, unless it can be shown definitely that there is

no danger of contamination. The procedures employed for this purpose are, in general, the same as those used in the chlorination of surface water (page 289). The chlorine may be added directly to the water in the well or it may be applied in the suction line or discharge pipe of the pump. In the larger installations, the water may be chlorinated after it has been pumped into a reservoir or standpipe.

The purification of water in wells that have become heavily contaminated by flooding, or in other ways, can be accomplished by the use of comparatively large quantities of calcium hypochlorite. A strong solution of the calcium hypochlorite is added to the water in the well in such amounts that the water will contain from 2 to 5 p.p.m. of free chlorine. After a contact period of at least 30 minutes, the well should be pumped until not more than 0.5 part per million of residual chlorine remains in the water (page 290).

SPRINGS

A spring is formed by ground water flowing out onto the surface of the ground. There are several kinds of geological formations which will cause the ground water to flow naturally onto the surface of the ground to form a spring. The surface of the ground may dip across the face of one or more impervious strata and the ground water streams carried by such strata; the direction of an impervious stratum may change so that it penetrates through the earth to the surface carrying with it an overlying layer of ground water, or a fault in an impervious stratum may permit the water confined below to escape to the surface of the ground.

Classification of springs. Springs are usually classified according to their origin as gravity and artesian. A gravity spring is formed by the ground water flowing by gravity onto the surface of the ground. Such a spring usually occurs where an outcropping of the uppermost impervious stratum forces an overlying stream of ground water to the surface.

An artesian spring rises from ground water flowing between two impervious strata. It may occur where a fault or fissure in the upper stratum permits the water to escape or where the surface of the ground cuts across the face of the overlying stratum.

The flow of a gravity spring may be constant or intermittent and tends to vary in quantity. The flow of an artesian spring is usually constant, with but little variation in quantity.

Contamination of spring water. Springs are natural wells and spring water is subject to the same sources of contamination as well water (page 235). A gravity spring is the counterpart of a shallow well and an artesian spring corresponds to a deep well, in so far as the source of the water and the sources of contamination are concerned. Spring water flowing from a fissure in a limestone formation has the same characteristics as well water which is recovered from a limestone stratum.

The methods of detecting contamination in spring water are the same as for well water (page 236). Contamination with surface water may be indicated by a flow which varies with the rainfall or by the appearance of, or an increase in turbidity after storms.

Protection of springs. A small spring should be protected by a water-tight reservoir, the size of which varies with the volume of flow and quantity of water desired. The reservoir should be so constructed as to prevent the entrance of surface water. It may consist of a concrete, masonry or wooden basin, preferably concrete. If built around the spring and without a bottom, the walls should extend down to the rock, if the spring flows from a rock ledge. If the spring is in loose material, the walls should extend for several feet into the earth in order to exclude surface water. A barrel with both ends removed or a large tile or pipe may be used in a similar manner to protect small springs (Fig. No. 31). Where practicable and feasible, a spring should be provided with a water-tight cover. A large spring may be developed as a source of water supply by the installation of an intake and pumps. A spring should be protected by drainage ditches or embankments in such a way as to prevent the entrance of surface water.

Purification of spring water. All spring water should be regarded as contaminated, except where an artesian spring, which does not flow from a limestone formation, can be adequately protected from contamination with surface water or with the ground water which flows above the uppermost impervious stratum of the adjacent terrain.

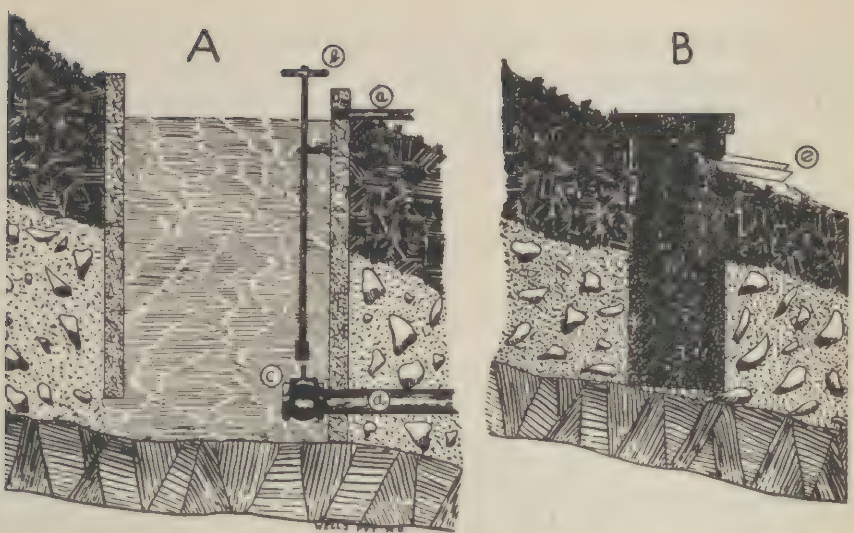


FIG. No. 31. Protected springs (Schematic). A—Concrete basin. B—Tile reservoir. a—Overflow pipe. b—Valve stem. c—Valve. d—Outlet. e—Outlet.

The purification of spring water is accomplished by the same methods as those employed for the purification of surface waters generally, except that, as spring water is usually clear, chlorination only is required.

Rate of flow of a spring. The rate of flow of a spring is ordinarily made by measuring the rate of flow of the outlet stream (page 223).

METHODS OF WATER PURIFICATION

A potable water is one which is free from disease-producing organisms and injurious chemicals. It does not have obnoxious tastes or odors, and is not turbid or colored to a degree which renders it objectionable for domestic use.

Water purification is the removal of foreign substances which are deleterious to health or which render the water unsuitable for domestic or industrial purposes. Water is purified by subjecting it to artificial or natural processes which remove or kill the pathogenic organisms. Water purification also includes the removal or reduction of turbidity, color, odors, tastes, hardness, and chemicals such as iron, manganese, or acids.

The methods employed in the purification of water are designed to eliminate contamination from the water either by actual mechanical removal, or by biological or chemical action. Four general procedures are used separately or in combination in the treatment of contaminated water to render it potable. They are:

a. Storage and plain sedimentation.
b. Filtration.
c. Chlorination.
d. Softening.

STORAGE AND PLAIN SEDIMENTATION

When the rate of flow of water is reduced, or the flow ceases, the particles of organic matter which have been held in suspension by the velocity of the water tend to settle out. Coagulation and precipitation of colloidal matter also occur. Under these conditions, a certain proportion of the bacteria present in the water are carried down by the precipitated substances while others are destroyed by the lack of proper food supply, by unfavorable environmental factors (sunlight, temperature, etc.) and by ingestion by microscopical animal organisms (infusoria, protozoa, etc.).

The time necessary to effect bacterial purification by storage alone varies with the conditions, such as the amount of sun and wind and the quantity and character of the organic matter. Given protection from concurrent contamination, storage alone will, under average conditions, eliminate the pathogenic bacteria from a body of water in from three to five weeks, none being added in the meantime through other sources.

Purposes and effectiveness of storage. Water may be stored as a means of effecting complete and final purification. The purpose of storage may be the accumulation of a reserve water supply for use during dry periods, or partial clarification by the removal of some of the suspended organic material preliminary to other purification procedures, such as filtration or chlorination.

Purification. The effectiveness of storage as a final purification measure depends largely upon the amount and nature of the organic matter present and the degree to which the stored

water can be protected from re-contamination. In order to purify water by storage there must be available a large reserve supply and facilities for storing such a supply. Further, while storage alone may, under proper conditions, destroy all of the pathogenic organisms, it will not completely clarify even moderately turbid water.

Because of the relatively large volume of water required, the comparatively long period of time necessary for bacteriological purification, and the supervision required to prevent re-contamination, storage alone is rarely a feasible measure for the purification of water under military conditions.

Storage for reserve purposes. The storage of unpurified water supplies during wet seasons for use during dry seasons is a common practice. This may be accomplished by natural storage in lakes and ponds or, artificially, in impounding reservoirs. Ordinarily, the vulnerability of such supplies to contamination from inflowing surface water and direct pollution, and the presence of turbidity which can not be removed by storage, preclude their use as drinking water without further purification.

Storage and sedimentation as a preliminary purification measure. The purification of water by filtration or chlorination is frequently preceded by storage and sedimentation in order to eliminate some of the suspended organic matter. Preliminary storage and plain sedimentation of highly turbid water will reduce greatly the amount of chemical required for coagulation prior to filtration (*infra*). Plain sedimentation may be accomplished in impounding or settling reservoirs. Settling or coagulation basins are used for the sedimentation of water which has been treated with a coagulant. Water having low turbidity may be clarified by storage preparatory to chlorination alone or prior to slow sand filtration and chlorination.

Impounding reservoirs. Impounding reservoirs are made by building a dam across a stream in such a manner that an artificial pond or lake is formed which retains in storage a comparatively large quantity of water. While impounding reservoirs are used principally for storing a reserve supply of water, a certain amount of purification occurs as the result of storage.

Settling reservoirs. Settling reservoirs are large basins or artificially constructed ponds into which water is introduced by pumping or by gravity and which are of such size that storage

for days or weeks is possible. Their function is to afford a period of storage during which plain sedimentation may take place. Storage of water in settling reservoirs is ordinarily employed as a prefiltration measure.

Smaller settling reservoirs serve to provide storage and plain sedimentation for periods of usually not more than a few hours, in order that a part of the suspended organic matter may be removed from turbid waters prior to coagulation or filtration.

Settling basins (*Coagulation basins*). The function, construction and operation of settling basins are described on page 247.

FILTRATION

In nature, ground water may be purified by filtration through soil which removes and retains the suspended organic matter. This natural process can be duplicated by the filtration of water through artificial beds of sand and gravel at a controlled rate and in predetermined quantities.

Theory of filtration. The removal of suspended material from water by filtration through sand is accomplished by a combination of several processes. The larger particles, that is, those that are larger than the interstices of the sand bed, are removed by simple mechanical straining. However, a filter will also retain particles and bacteria which are much smaller than the spaces between the sand grains and will remove, to a greater or less extent, suspended colloids, such as vegetable coloring matter or colorless organic matter. The filtering action of the sand bed therefore involves processes other than mechanical straining.

After a filter has been in operation for a time, the grains of sand, particularly those near the surface, become coated with a thin gelatinous film. This film is composed of organic matter, living and dead, and inorganic material in a colloidal form. The sand grains form a supporting network for the mesh-like mass of gelatinous, colloidal matter which forms the actual functioning part of the filter. While the water diffuses readily through this structure, the suspended colloids, bacteria and minute particles of organic matter are retained by the gelatinous film on the sand grains and in the spaces between the grains.

It is possible that electrolytic action may occur between the colloidal particles resulting in the coagulation and sedimentation of those suspended in the water. In any event, the formation of the gelatinous film is a vital factor in the operation of a sand filter.

The gravity rapid sand filter. The gravity rapid sand filter is the type of filter most commonly used for the filtration of water in the military service. The rapid sand filter is characterized by the use of a chemical to coagulate the suspended organic matter, sedimentation of the coagulated material prior to filtration, the rapid passage of the water through relatively small filter units, and cleaning by mechanical methods which permit rapid washing without removal of the sand from the filter. The typical rapid sand filter plant consists essentially of coagulating basins, filter units, chlorinating apparatus, clear water reservoirs, and such installations and appliances as may be necessary for the handling, storing and application of chemicals, and the distribution of the water.

Principles of rapid sand filtration. The rate of filtration through a rapid sand filter varies from 100,000,000 to 150,000,000 gallons per acre of filter surface per day, the average being about 125,000,000 gallons, or 120 gallons per square foot of filter surface per hour. In order that efficient filtering action may be obtained despite the rapid passage of water through the filter, the organic matter suspended in the water flowing onto the filter must be present in such quantity and in such form that the sand grains are quickly coated and the surface mat is rapidly formed. The rapid accumulation of organic matter in the sand of the filter necessitates frequent and effective cleaning. To meet this requirement the sand is washed in the filters by mechanical means and the methods employed in washing necessitate the use of relatively small filter units.

Coagulation. Most of the surface waters in the United States contain suspended material such as silt and clay, and in some instances vegetable coloring matter, which long periods of sedimentation or filtration without coagulation will not entirely remove. In the treatment of such waters it is necessary to add a chemical which will produce coagulation, with subsequent precipitation of the suspended matter and partial clarification of the water. The chemicals usually employed

as coagulants are the single or double sulphate of aluminum (alum), ferrous sulphate or ferric salts, and lime. Alum is utilized to a much greater extent than iron in water purification and is employed at practically all army water purification plants.

The ferrous and ferric compounds used as coagulants are ferrous sulphate, ferric chloride and chlorinated copperas. The latter is a mixture of ferrous sulphate and ferric chloride prepared by treating ferrous sulphate with chlorine.

Ferrous sulphate, or copperas, together with lime, has been used as a coagulant in a few plants for many years. Ferrous sulphate is effective only in the coagulation of waters having high pH values. More recently ferric chloride, and also chlorinated copperas, have been found to yield better results than ferrous sulphate in the treatment of certain waters, as they are effective coagulants over a much broader pH range and can be used to coagulate acid waters. Coagulation with ferric salts is also used in the treatment of some waters for the removal of iron or manganese.

Waters differ greatly in their characteristics and the same water may from time to time exhibit marked changes in its chemical and physical properties. Consequently, the coagulant and the methods of coagulation best suited for the treatment of a given water supply must be determined in each instance. The general principles of coagulation are discussed below, but the details of procedures to be used in the operation of any plant must be based on experience in the treatment of that particular water supply.

When alum is added to water containing alkaline carbonates (calcium or magnesium carbonates), aluminum hydroxide is formed. The aluminum hydroxide has a large colloidal molecule and, being insoluble, it forms a gelatinous, jelly-like, flocculent substance which breaks up into minute particles or coagula called floc. The visible floc vary in size from those that are barely discernible to large feathery flakes. The floc during their formation entrap or envelop particles of organic matter including bacteria, absorb coloring matter and gases in solution in the water and cause the coagulation of the finely divided or colloidal silt, clay or other organic matter. The floc, or coagula, of aluminum hydroxide and organic matter, while they appear to be floating in the water,

gradually settle out leaving, if proper conditions have been present, a bright, clear and attractive water.

The reaction in water is as follows:

$$Al_2\,(SO_4)_3 + 3\,CaH_2\,(CO_3)_2 = 2Al\,(OH)_3 + 3CaSO_4 + 6\,CO_2$$

aluminum sulphate	*calcium bicarbonate*	*aluminum hydroxide*	*calcium sulphate*	*carbon dioxide*

The amount of alum required to coagulate the water depends on the quantity and character of the turbidity, organic matter, mineral content, and color and varies from 0.5 to five grains per gallon, the average being about one grain per gallon. Theoretically, the complete reaction requires 7.7 parts per million of alkalinity for each grain per gallon of alum. Actually, as apparently the alum combines with other substances in the water, from 4 to 7 p.p.m. of alkalinity are required for each grain per gallon of alum. There should be an excess of at least 10 to 25 parts per million of alkalinity above that required for the alum reaction in order to prevent corrosion (page 332). If the alkalinity is insufficient, the alum will remain in solution as the basic salt. Deficient alkalinity may be corrected by adding 0.5 grain of sodium carbonate (soda ash), or 0.35 grain of lime, for each grain of alum used.

The alkalinity, or acidity, of water is commonly expressed as the hydrogen ion concentration, or pH value. In the coagulation of any water supply there is a range of pH values within the limits of which the most satisfactory coagulation occurs. This optimum zone varies for different waters but is usually somewhere between pH 5.5 and pH 7.5. The optimum zone within which the best coagulation occurs in a given water is determined by tests and experimental operation. It is usually found that the most satisfactory coagulation reaction takes place within a fairly narrow range of pH values, for example, between pH 6.0 and pH 7.0. The efficiency of the coagulation reaction is affected but little by variations in the pH values in the central part of the optimum zone, but diminishes rapidly as the limits of the zone are approached.

Control of the hydrogen ion concentration affords the best method of controlling the coagulation reaction. The tests to determine the pH values are simple and require very little time and no elaborate equipment or extensive laboratory training. The quantity of chemicals which must be added to the

water to maintain the hydrogen ion concentration at the desired point is determined by the results of the tests of the pH value.

The alum used to effect coagulation reduces the alkalinity of the water and, consequently, where correction of the pH value is required, it is, as a rule, necessary to add an alkali, usually soda ash or lime. The methods of applying chemicals for the correction of the pH value are the same as those used in applying alum (*infra*) (page 267).

In the coagulation of soft, colored water, it may be necessary to use a relatively low pH value in order to accomplish satisfactory coagulation and color removal. The application of an acid, usually sulphuric acid, may be required to correct the hydrogen ion concentration to the optimum pH value. Frequently, it is also necessary to use larger doses of alum —from three to five grains per gallon in order to obtain satisfactory removal of the color. It may be necessary to add an alkali, usually lime, to the filtered water to prevent corrosion (page 332).

The time required for coagulation varies from a few minutes to a number of hours, depending upon the quantity and character of the suspended organic matter, the amount of coagulant used, the pH of the water, the temperature, and the mixing. The average time required for coagulation and sedimentation, where the water is to be filtered through rapid sand filters, is from two to six hours. The efficiency of coagulation in the removal of bacteria is augmented by prolongation of the coagulation time to from eight to twelve hours.

Under certain conditions the efficiency of the coagulation reaction is increased by double-stage coagulation. The coagulant is applied in divided doses at different stages of the coagulation process. Sedimentation may be carried out in one or in two stages.

Laboratory tests should be made to determine the efficiency of the coagulation reaction. However, in the absence of laboratory tests the appearance of the water will indicate roughly if the reaction is satisfactory. Usually, if the water is "smoky" and no distinct floc are present, soda ash should be added. If the floc are large and feathery the amount of alum should be reduced. The amount of turbidity in the water should be reduced to not more than 10 to 25 parts

per million as the water flows from the settling basins to the filters.

Settling basins (*Coagulation basins*) (Fig. No. 32). The settling basin serves to decrease the flow of the water while sedimentation of the organic matter takes place.

Settling basins are usually made of concrete. The size of the basins for any particular plant depends upon the capacity of the plant and the length of time required for sedimentation. Many basins are provided with baffles which serve to increase the length of the retention period and prevent short circuiting of the flow, and thus insure a more complete precipitation of the flocculent sediment.

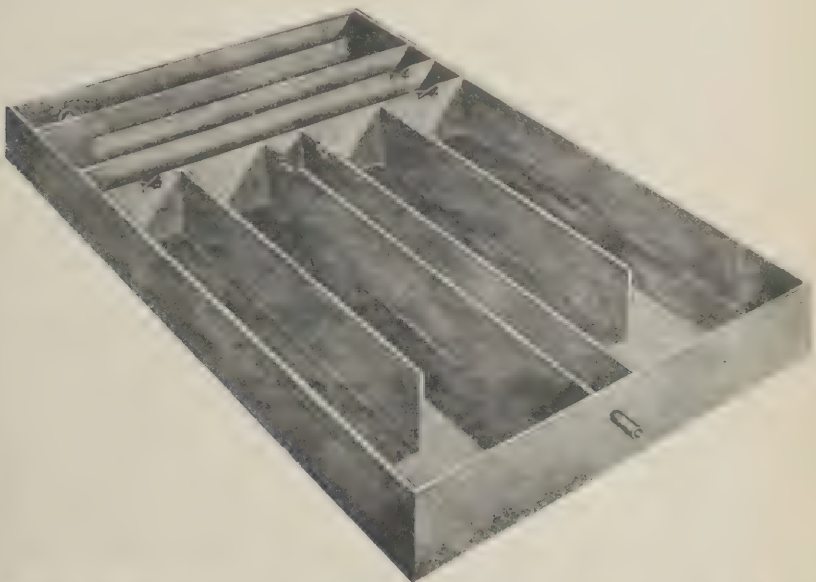


FIG. No. 32. Two settling basins having common mixing channels and effluent channel (Schematic).

Coagulation procedures. All coagulation procedures are designed to produce a compact floc of proper size that will settle out in the settling basins. The first and the most important step in coagulation is the mixing of the chemical solutions with the water. Efficient coagulation requires that the coagulant be uniformly distributed through and properly mixed with the raw water. Usually this is accomplished by applying the

coagulant in solution to the water in mixing basins or channels. The mixing basin may be constructed as an integral part of the settling basin or as a separate installation. In some instances the coagulant is mixed with the water in a conduit or in passage through pumps. Occasionally, it is added to or mixed with water in the settling basin. Mixing basins, or tanks, may be equipped with power driven paddles.

Mixing basins or channels should be designed to provide initial mixing at a relatively high velocity with a decreasing flow thereafter. The basins may be constructed with around the end baffles or with cross baffles to produce an up and down flow.

The raw water containing the coagulant should flow through the mixing channels with sufficient velocity to effect a thorough and uniform mixing of the chemicals with the water and a more or less complete coagulation, without breaking up the floc or permitting the sediment to settle out. In practice, the rate of flow through the mixing channels is usually from one to three feet per second and the time of flow from 10 to 40 minutes.

The outlet from the mixing basin or channel to the settling basins must be of sufficient capacity to prevent an increase in velocity which would break up the floc.

The coagulated water passes through the settling basins at a rate of from a few inches to two feet per minute during a retention period of from 2 to 12 hours. If the rate of flow is too rapid, or the retention period too short, too much of the finer sediment will be carried over onto the filters and result in rapid clogging of the sand. If the rate of flow is too slow, or the retention period too long, the capacity of the plant is decreased, and in some cases not enough sediment will reach the filters to produce effective filtration.

Cleaning of settling basins. As the mud and sediment accumulate on the bottom of a settling basin, the basin becomes shallower and the rate of flow increases, unless the amount of water treated is reduced. Consequently, the basins must be cleaned whenever the depth of the sludge on the bottom becomes sufficient to reduce the capacity of the basin to a point where the velocity of the flow is so great that proper sedimentation no longer occurs. The amount and character of the mud which will accumulate in a settling basin depends on

the quantity and the character of the organic matter in the water. In some plants the basins must be cleaned at frequent intervals, while in others a much longer time may be permitted to elapse between cleanings without detriment to the efficiency of the plant.

Wherever practicable, settling basins should be equipped with cleaning devices such as the Link-Belt collector or Dorr clarifier. The methods employed are similar to those used to remove sludge from sewage sedimentation tanks (Chapter XIV page 623).

Where mechanical apparatus is not available for cleaning the basins, the floor of each settling basin may have a decided slope, at least five per cent, to a centrally placed drainage sump or gutter. In cleaning the basin, the water is drawn off, after which the mud may be flushed into the drainage sump or gutter by water under pressure. The mud may be

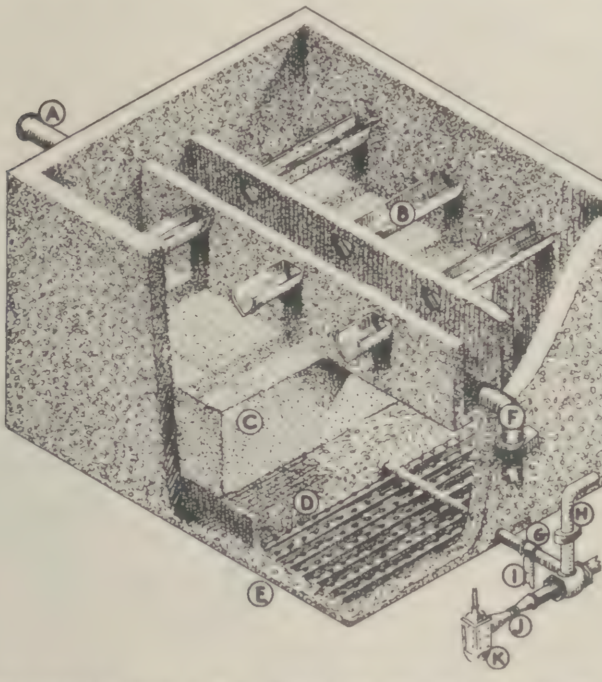


FIG. No. 33. Rapid sand filter unit (Schematic). A—Inlet. B—Wash water troughs. C—Sand bed. D—Gravel layer. E—Under drain (strainer) system. F—Waste water drain pipe. G—Effluent pipe. H—Wash water pipe. I—Drain pipe to sewer. J—Venturi tube. K—Effluent valve (rate controller).

removed with hand scrapers, usually in conjunction with flushing.

The control of tastes and odors caused by decomposition of the sludge in a settling basin is discussed under the control of tastes and odors (page 317).

Rapid sand filter. A filter unit of a modern rapid sand filtration plant consists of an open top, concrete tank, usually rectangular in shape, containing a layer of gravel which supports a bed of sand. On the bottom of the tank under the gravel are the underdrains which carry away the filtered water. Above the sand bed are the wash water troughs or gutters which carry away the dirty water that has been used to wash the sand (Fig. No. 33).

Ordinarily, each unit has a filtering capacity of from 500,000 to 1,000,000 gallons per day, although larger, as well as

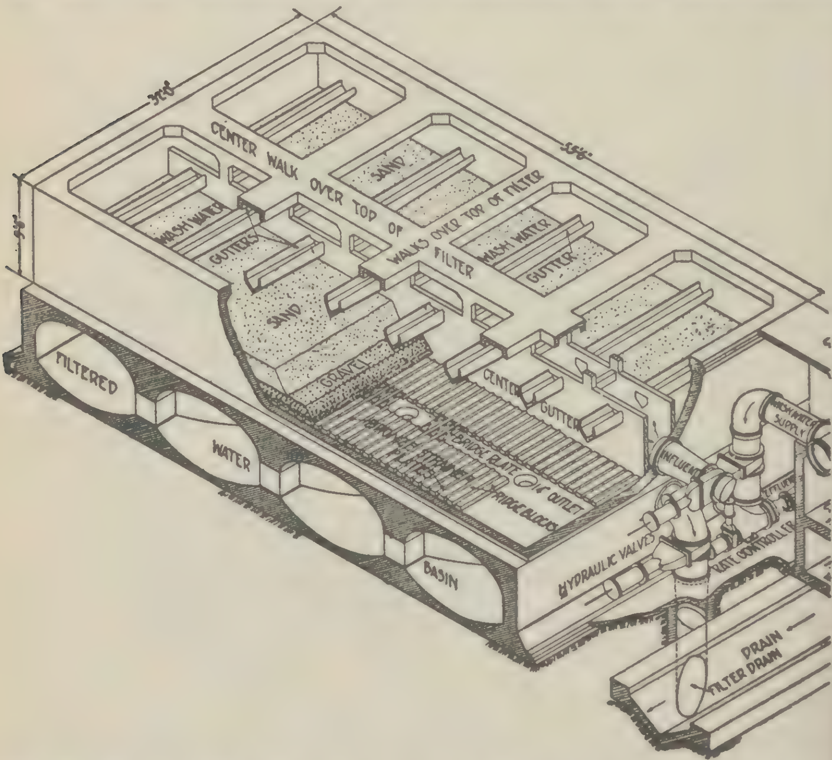


FIG. No. 34. Isometric view of rapid sand filter unit showing relation of the various structural features. (Courtesy of the Bureau of Water Supply, Department of Public Works, City of Baltimore, Maryland).

smaller, units may be used. A filter unit having a surface area of 175 square feet has an approximate filtering capacity of 500,000 gallons per day.

In some of the older plants a circular wooden or steel tank is used instead of a concrete basin. A circular tank having a diameter of ten feet has a filtering capacity of approximately 225,000 gallons per day.

The underdrains. (*Strainer system*). On the floor of the filter are the underdrains consisting of a series of pipes, channels or gutters which collect the filtered water and carry it to the effluent pipe. The underdrains also admit and distribute the wash water, which is forced upward through the gravel and sand to the wash water troughs above the sand bed. In some plants the underdrains also carry the air used to agitate the sand during washing (Figures No. 35 and 37).

The underdrains may consist of a pipe manifold, or grid, with lateral pipes placed at right angles to, and draining into, a central main collector which bisects the floor of the filter (Fig. No. 35). The pipes are either laid on or are embedded in the concrete floor of the filter. The lateral pipes are from 1¼ to 2 inches in diameter and placed about six inches apart. The central collecting pipe is from 8 to 10 inches in diameter. Brass perforated or slotted strainers are screwed into the upper surface of the lateral pipes and project upward into, and are surrounded by, the gravel. The strainers are placed about six inches apart. In lieu of strainers, the lateral pipes may be perforated with ¼ inch holes placed from 3 to 6 inches apart. In plants where air is used in washing, the pipe underdrains may carry the air to the filter (page 259).

The underdrain system may consist of concrete channels in the floor of the filter. These channels are about three inches deep, from two to three inches wide and covered with perforated brass plates. They are spaced about one foot apart and may run at right angles to and empty into a central gutter, or they may drain into pipes placed below the floor of the filter (Fig. No. 36). In the latter case, the channels are connected at about 12-foot intervals with pipe risers which carry the water into pipes below the filter floor. If a central gutter is used, outlets in the floor of the gutter deliver the water into effluent piping below. This system is used either with the high velocity method of washing or in connec-

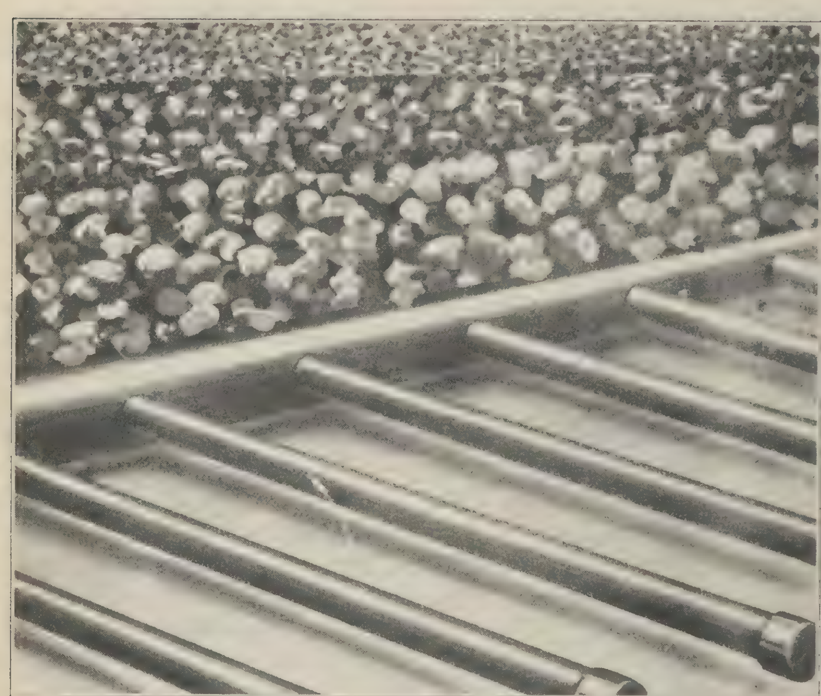


FIG. No. 35. Underdrains with perforated lateral pipes leading into main drain. (Courtesy of the International Filter Co., Chicago, Ill.).

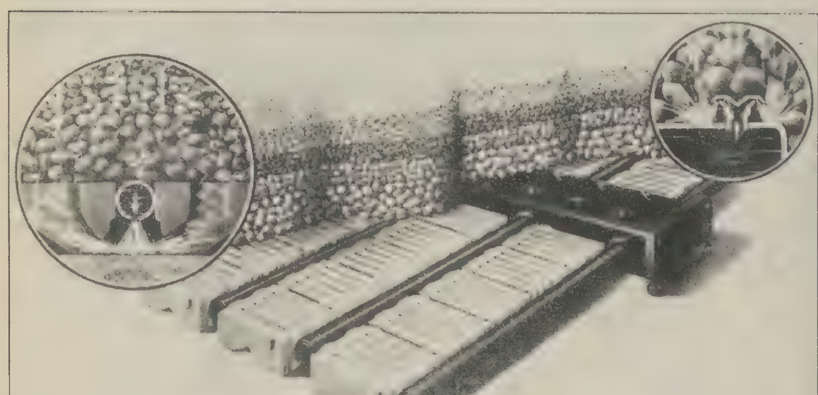


FIG. No. 36. The Wagner filter drain showing the spaces between the laterals filled with slotted concrete blocks. (Courtesy of the International Filter Co., Chicago, Ill.).

FIG. No. 37. Diagrammatic section of rapid sand filter showing perforated lateral drains delivering wash water. (Courtesy of the International Filter Co., Chicago, Ill.).

tion with the air and water method. If air is employed, separate piping is installed to carry the air into the filter.

The gravel layer. Above or surrounding the underdrains, is a layer of gravel, the principal function of which is to support the sand bed and prevent the water from carrying the sand into the underdrains. The gravel layer is from 10 to 18 inches thick and consists either of pea size stones throughout or of graded gravel ranging from stones two to three inches in diameter at the bottom to coarse sand at the top (Fig. No. 33).

The sand bed. The sand bed is the true filtering medium, as but little filtering action takes place in the gravel layer. The size, and uniformity in size of the sand grains are important factors in the operation of a filter. Two constants are employed in classifying the size of filter sand—the effective size of the grains and the uniformity coefficient.

The effective size is the size of the grains which are larger than 10 per cent, by weight, of the grains contained in the sample tested. Thus, if the effective size of a sample of sand is 0.3 millimeter, then 90 per cent of the sand grains are more than 0.3 millimeter in diameter. Or, if the sample of sand is passed through a 0.3 millimeter mesh of square mesh screen, 10 per cent will pass through the screen and 90 per cent will be retained. The uniformity coefficient is the ratio between the effective size and the size of the grains which are just larger than 60 per cent, by weight, of the grains contained in the sample tested. Thus, if 10 per cent of the sample will pass through a 0.3 millimeter mesh and 60 per cent through a 0.6 millimeter mesh, the uniformity coefficient is 2.0.

The sand used in a rapid sand filter usually has an effective size of from 0.35 to 0.6 millimeter, with a uniformity coefficient of about 1.5, but there is a growing tendency to use coarser sand.

Wash troughs. Within the filter tank and above the sand beds are the wash troughs or gutters which serve primarily to collect and carry away the dirty wash water. Usually, especially in the larger filters, there is a central gutter or conduit and a number of lateral troughs. The central gutter may or may not be covered, but the lateral troughs are uncovered. The lateral troughs collect the wash water and convey it to the central gutter through which it flows to a drain pipe lead-

FIG. No. 38. View of the interior of a rapid sand filter unit before the gravel and sand have been put in place, showing wash water troughs and underdrains. Fort Knox, Ky.

ing to a sewer. The main or collecting gutter may be located at the side or end of the filter instead of in the center.

The wash troughs are made of concrete, steel plate or cast iron. The typical lateral trough has a V shaped bottom with vertical sides and smooth edges. The edges of the lateral troughs act as weirs which draw the water at a uniform rate from all parts of the filter. The lateral troughs are placed not more than six feet apart from center to center. The top of the trough is usually from 20 to 24 inches above the sand bed (Fig. No. 34).

Operation of a filter unit. The settled water flows by gravity from the settling basins onto the filter. Where possible, the relation between the coagulation basins and the filter should be such that there is very little or no difference in head (*infra*) in order that valves will not be required to regulate the flow of water onto the filters. Irregularities in flow tend to disturb the filtering action of the sand bed and impair the efficiency of the filter.

The depth of water over the sand bed depends upon structural and operating conditions and varies in different plants from three to eight or nine feet.

The amount of coagulated sediment in the water which can be efficiently removed by the filter will vary with the character of the sediment, the temperature, and the rate of filtration. The water must contain some floc in order that the gelatinous coating will be formed on the sand grains. If it contains too much floc, the filter will clog in a short time, with a consequent loss of head, and will require frequent washing. In actual practice, the water admitted to the filter may at times contain as much as 100 parts per million of sediment, but the average should not be more than 10 to 25 parts per million.

Loss of head. The term head as expressed in feet is used in the measurement of water pressure and represents the height to which a column of water will rise against the pull of gravity alone. Thus, water flowing through a pipe from the bottom of a basin containing ten feet of water will, if the pipe is extended vertically outside the basin, rise to a height of ten feet in the pipe, and, therefore, the water where it leaves the basin has a head of ten feet. One foot of head, or a column of water one foot in height, exerts a pressure of 0.434 pounds per square inch. One pound of pressure per square inch will raise water to a height of 2.3 feet.

Water flowing through a pipe, conduit or filtering material, such as sand or soil, meets with resistance due to friction between the moving water and the stationary substances against which it impinges. This frictional resistance reduces the velocity of the flow and decreases the head or pressure exerted by the water, producing loss of head (Fig. No. 39).

The sand bed of a filter exerts resistance to the flow of the water which varies according to the quantity of organic matter contained in the sand. In a clean filter, the resistance is slight, the loss of head being only three or four inches. That is, the water issuing from the underdrains if discharged into an upright pipe would, theoretically, rise to within three to four inches of the surface of the water on the filter. As filtration proceeds, and the upper portion of the sand bed gradually becomes filled with the organic matter filtered out of the water, the frictional resistance to the flow of water

increases. As the frictional resistance increases, the head of the water flowing from the underdrains is decreased (Fig. No. 39). Loss of head is measured by instruments devised for this purpose (page 279).

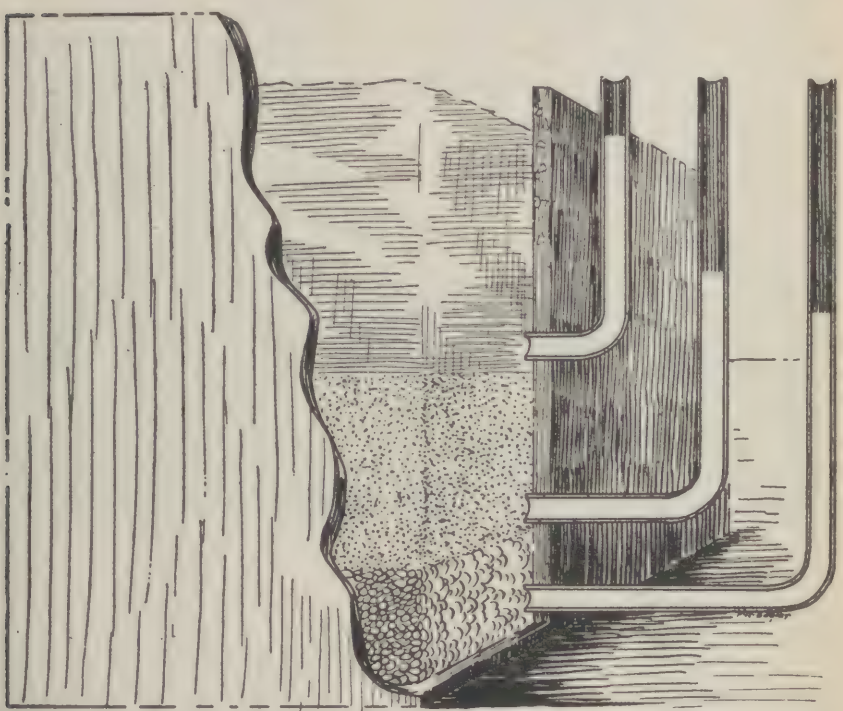


FIG. No. 39. Loss of head diagram showing loss of head due to frictional resistance to the flow of water through the sand bed and gravel layer.

When the loss of head exceeds the total head, or depth of water above the sand, a negative pressure, or suction, is created in the upper layers of the sand bed. As this negative head increases there is usually a decrease in filtering efficiency, which is largely due to the higher velocity of the water flowing between the sand grains at the surface of the filter.

The loss of head indicates the degree of clogging of the sand. In any given filter it can be determined that a certain loss of head will be followed by deterioration in the quality of the filtered water. Thus, the loss of head can be utilized as a measurement of the filtering efficiency of the filter and

as a means of determining when the filter should be washed. The loss of head which indicates that the filter must be cleaned is determined for each filter and varies within limits for different filters according to the size of the sand, the amount and the character of the sediment, and the depth of water on the sand. Ordinarily, the average rapid sand filter is washed when the loss of head amounts to from seven to ten feet.

While the duration of a filter run is primarily determined by the loss of head, frequently in actual practice the filter units of a plant are washed after they have been in operation a predetermined number of hours, even though the maximum loss of head has not been reached. The length of the filter run is determined by experience in filtering water of various turbidities.

Washing the filter. The sand is cleaned in the filter by being washed in a stream of water which is forced upward through the sand. Water under pressure is admitted to the strainer system and as it passes upward through the sand, the sand grains are floated and the lighter sediment is carried upward by the water to a point above the sand. The sediment adhering to the sand grains is removed by friction between the grains floating in the wash water. As the wash water flows upward through the sand, the sand bed as a whole expands by increasing in depth, the amount of expansion depending on the velocity of the wash water. Under average conditions, the sand bed expands about fifty per cent when the velocity of the wash water is the greatest. The velocity of the water is so adjusted that it overflows into the wash water trough carrying with it the light dirt and sediment, but not the heavy sand. When the current of water is shut off the sand grains settle down onto the underlying gravel layer. The velocity of the water and the time of washing are such that a small amount of the gelatinous film remains on the grains of sand to start the filtering action in the otherwise clean filter.

Filtered water is always used for wash water and it may be supplied to the filters from a tank placed at an elevation which will provide the necessary head, by means of pumps which pump the wash water to the filters from the filtered water reservoir, or through a connection with a pressure line (Fig. No. 40).

FIG. No. 40. Wash water tank for rapid sand filter. Wash water applied by gravity.

The wash water reaches the underdrains through a wash water pipe which is connected to the main effluent pipe of the filter between the filter and the effluent valve (Fig. No. 33).

Methods of washing. The two methods employed in washing the rectangular filters are the high velocity wash and the air and water wash. In washing circular filters, revolving rakes are frequently used to agitate the surface of the sand.

When the filter is to be washed by the high velocity method, the valve in the influent pipe, which admits the water from the coagulating basins to the filter, is closed. Filtration is continued until the water on the filter is drawn down to the level of the top of the wash water troughs, when the effluent valve is closed. The valve connecting the wash water troughs and piping with the sewer is then opened, after which the valve admitting the wash water to the underdrain system is slowly opened. It is essential that the velocity of the wash water be relatively low at the beginning of the washing period in order that the finer grains of sand on top of the filter will be cleaned

by friction against each other before being widely separated by the wash water.

The velocity of the wash water best suited for washing a given filter depends to some extent on the design and methods of operating the plant. Generally, the velocity should be as great as can be employed without causing sand to be carried away, which in most instances is from ten to fifteen gallons per square foot of filter surface per minute. Greater velocities are used where the character of the sand and the design of the plant will permit. The velocity of the wash water is also expressed as the rate of upward flow through the sand, or the vertical rise. In most plants, the average vertical rise is two feet per minute.

The time of washing is determined by the clarity of the wash water, and is usually from three to ten minutes. The final wash water should have a turbidity of from 75 to 100 p.p.m. As, under working conditions, the turbidity of the wash water must be estimated by inspection, it is customary to consider the washing as complete when large clear areas appear in the wash water.

When washing is completed, the wash water valve is slowly closed; the sewer valve is closed, and the influent valve is opened sufficiently to bring the water on the filter to the normal level. The water is then allowed to filter to waste through a valve and pipe connecting the effluent pipe with the sewer until the filtered water is clear (Fig. No. 33). The time during which the water must be filtered to waste varies, but a satisfactory effluent can usually be obtained in from three to ten minutes. The effluent valve is then opened and the filtered water passed to the clear water reservoir. Where it is not necessary, or not practicable to filter to waste, the washed filter is allowed to stand idle for a short period of time so that the sediment or floc in the overlying water will settle down onto the sand and form a new surface mat. The filter can then be started without filtering to waste.

Where the air and water method of washing is used, the influent valve is closed and the water drawn down to within a few inches of the surface of the filter. The effluent valve is then closed and air admitted through the strainer system or through separate air piping. The air is applied at the rate of from two to five cu. ft. of air per square foot of filter surface per minute

for from 3 to 4 minutes. The air serves to agitate the sand and, to a certain extent, separates the sand grains and frees them from the heavy sediment. After agitation with air has been accomplished, the air valve is closed and the wash water and sewer valves are opened. The filter is then washed in the same manner as by the high velocity method, except that the velocity of the wash water is less, the water being applied at the rate of from seven to ten gallons per square foot of filter surface per minute for from three to five minutes. The average time required for complete washing is about fifteen minutes. The filter is placed in operation after washing in the same manner as when the high velocity wash method is used (*supra*).

The high velocity method is used to wash filters of the circular type. While the wash water is flowing through the filter, the surface of the sand is agitated by rakes which revolve at the rate of from 12 to 14 revolutions per minute.

Frequency of washing. The frequency with which a filter must be washed depends upon the amount of sediment carried over onto the filter and the rate of filtration. If a large amount of sediment must be removed by the sand, or the rate of filtration is high, the sand clogs quickly and the filter must be washed at comparatively short intervals. Under average conditions, the time between washings varies from 6 to 24 hours. Where the plant is operated only a part of each day, the filters should be washed at the end of each day's run.

Defects in washing. While as much as possible of the heavy sediment and mud should be carried away in the wash water, the filter should not be left absolutely clean. The velocity of the wash water and the time of washing should be so controlled that a thin film of sediment is left on the sand grains and on the surface of the sand layer. Otherwise, an excessive quantity of water must be filtered to waste after washing before a satisfactory effluent is obtained.

The presence of mud evenly distributed over the surface of the sand after washing, accumulations of mud near the wash water troughs, or the development of mud balls in the sand usually indicate that the velocity of the wash water is too low, the time of washing is too short, or that the wash water troughs are too far apart or too high above the surface of the sand. The formation of cracks in the sand indicates that mud has been carried into the sand because of insufficient washing.

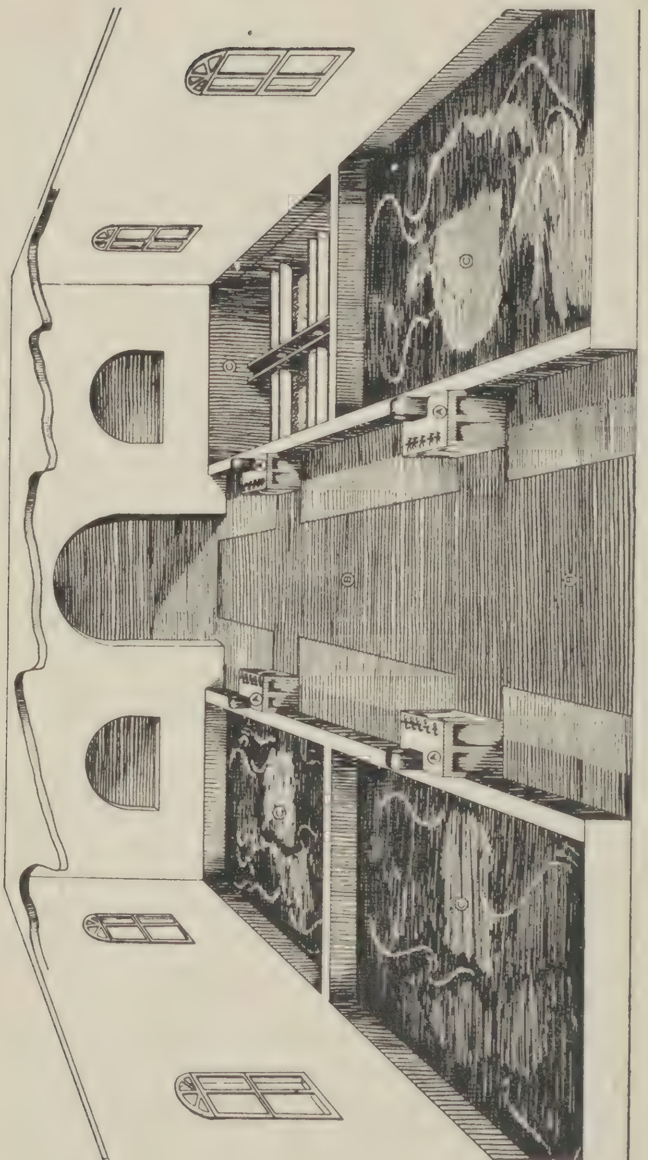


FIG. No. 41. Schematic representation of a filter house, showing arrangement of filter units. A—Operating cabinet. B—Operating floor. C—Filter units.

Craters in the surface of the sand and the occurrence of mud in isolated areas are usually due to breaking or clogging of strainers or holes in the underdrains through which the incoming wash water flows.

Mixing of the gravel with the sand is usually due to turning the wash water on too rapidly or to an excessive velocity of the wash water. The loss of sand in the wash water is usually caused by high velocity of the wash water or, with moderate velocity of the wash water, it may occur if the wash water troughs are too close to the surface of the sand bed.

The effectiveness of washing in the removal of mud may be determined roughly by squeezing in the hand a small quantity of the sand taken from the surface of a freshly washed filter. If the sand contains too much mud, the grains will adhere together and the hand will be mud stained. The grains of properly cleaned sand will not adhere to each other nor will such sand stain the hands.

Prevention and correction of conditions due to defective washing. Occasionally, after a filter is washed, the water should be drawn down below the surface of the sand and the sand bed inspected. Isolated accumulations of mud, or mud balls, should be carefully removed with shovels. Cracks in the sand bed can be eliminated by removing the mud causing the cracks and refilling the area with clean sand.

The replacement or repair of broken or clogged strainers necessitates the removal of all or part of the sand and gravel from the filter. However, as long as the filter will effect proper bacterial and turbidity reduction, the conditions resulting from a few defective strainers will not justify the expense of removing the sand and gravel from the filter.

The loss of sand in the wash water may be determined by taking samples of the water from the troughs while the filter is being washed. These samples are allowed to settle in large glass jars or bottles and the sediment examined for the presence of sand.

The development of defects in the filter can be prevented or minimized by close attention to the washing of the filter and by frequent inspections. The efficiency of a rapid sand filter unit depends to a very considerable degree upon carefully controlled coagulation and sedimentation of the water and proper washing of the sand.

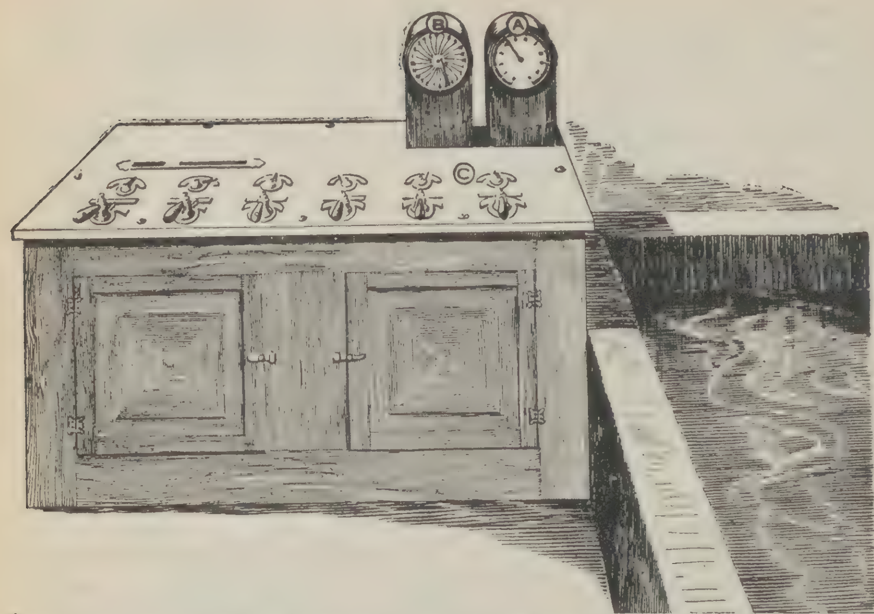


FIG. No. 42. Operating cabinet. A—Loss of head gauge. B—Rate of filtration gauge. C—Valve handles and gauges. (Schematic).

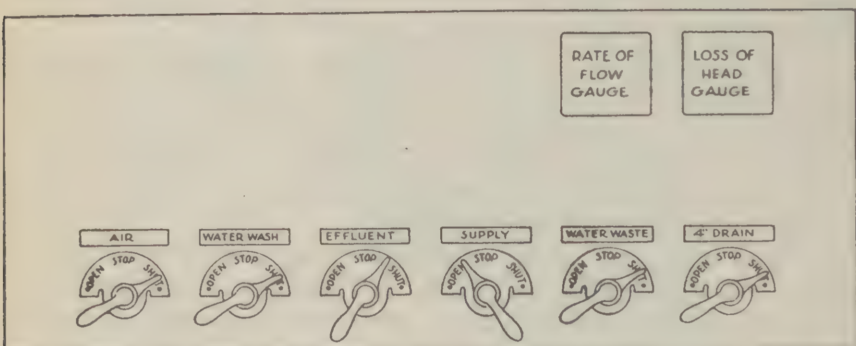


FIG. No. 43. (Schematic) Top of operating cabinet showing location of valve handles and gauges.

Arrangement of filter units (Fig. No. 41). The filter units are so placed that close supervision is facilitated and the operator can watch the filter while manipulating the valves by which the washing procedures are controlled.

As a rule, a filter plant has two or more filters, in order that one or more can be thrown out of service without ces-

sation of filtration. These units are usually placed in two parallel rows between which there is an operating floor. The operating floor provides space for the valve stands and gauges or operating cabinets. Under the operating floor is a pipe gallery which affords space for, and renders accessible for inspection and maintenance, the various pipes, conduits and valves which are necessary in the operation of a rapid sand filter (Figures No. 45 and 46).

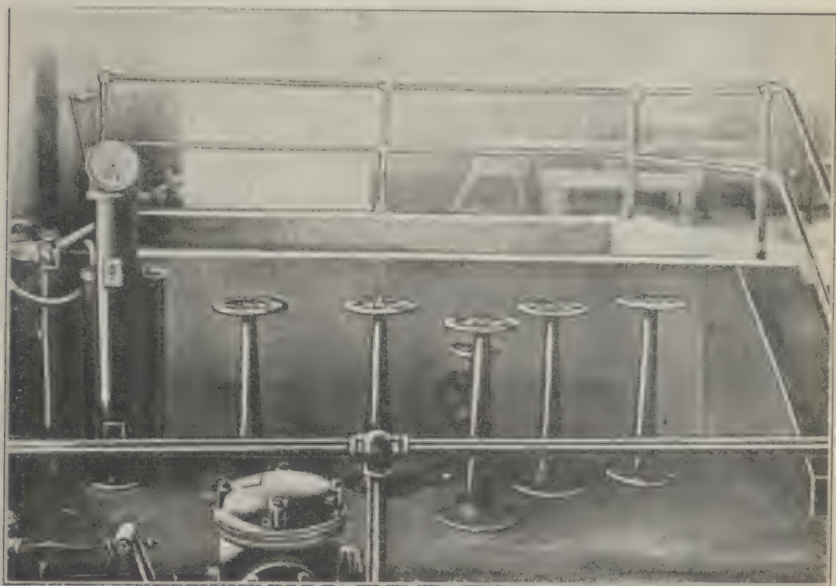


FIG. No. 44. Filter unit equipped with hand operated valves instead of operating cabinet.

Valve stands and operating cabinets. The valves required for each filter unit are the influent, the effluent, sewer, wash water, filter to waste and, where air is used, an air valve. In the smaller plants where hand operated valves are frequently employed, the valve wheels are placed on extension stems which are grouped on the operating floor near the filter unit. The gauges showing the rate of flow and the loss of head are located on the operating floor near the valve stands (Figures No. 42, 43 and 44).

In larger plants, hydraulic, or electrically controlled valves are used, and the levers and indicators for these valves are placed on top of an operating cabinet or table adjacent to

the filter unit to which they pertain (Figures No. 42 and 43). The loss of head and rate of flow gauges may also be placed on the operating cabinet, together with sampling faucets or sight tubes which enable the operator to observe and judge the character of the influent and effluent.

The clear water reservoir. The clear or filtered water reservoir or basin receives the filtered water from the effluent pipe of the filter. It may be a concrete tank underneath the filter unit proper, in which case the roof of the clear water basin forms the floor of the filter (Fig. No. 34). In other

FIG. No. 45. Modern rapid sand filtration plant showing relation of filters, operating cabinets and operating floor. (Courtesy of the Pennsylvania Department of Health, Harrisburg, Pa.).

instances, a clear water reservoir is placed at varying distances from the filter. It should be covered to inhibit the growth of algae and to prevent contamination with foreign substances. The size and capacity of the clear water reservoir varies in different plants and is determined by the rate of filtration, the rate of consumption, and methods of distribution. The water may flow by gravity, or be pumped, from the clear water

reservoir directly into the mains of the distribution system or it may be passed to another reservoir for storage and subsequent distribution.

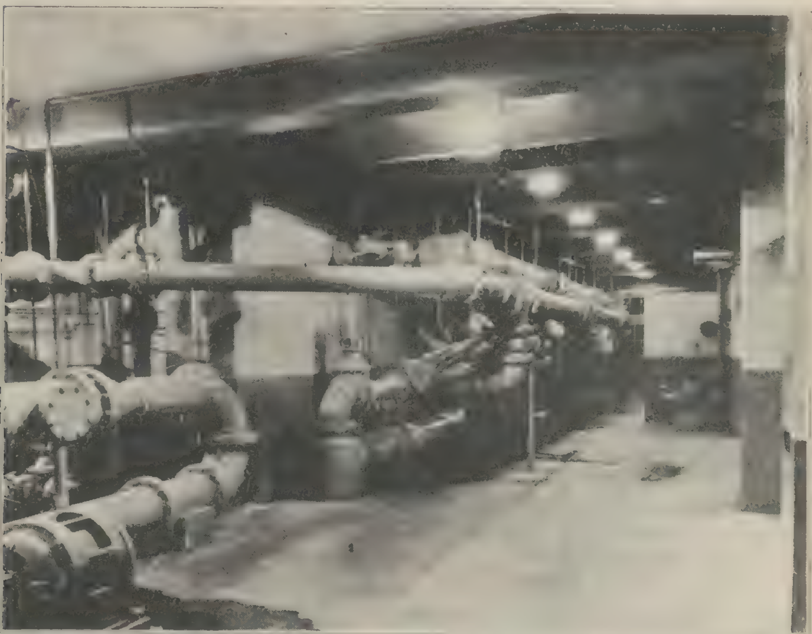


FIG. No. 46. Pipe gallery located below and between filter units of a rapid sand filter. (Courtesy of the International Filter Co., Chicago, Ill.).

Application of chemicals. (*Alum and soda ash*). The two chemicals ordinarily used in rapid sand filtration of water are alum and sodium carbonate (soda ash). They may be applied to the water either in solution or dry.

When water is treated with chemicals in solution, a standard strength solution is applied at a given rate proportional to the flow of the water being treated. The strength of the standard solution of alum is usually two per cent and that of the soda ash from two to five per cent.

Solutions of alum should be prepared and stored in concrete or wooden tanks. Alum will not ordinarily cause the deterioration of concrete. Wooden tanks are satisfactory and are frequently used in the smaller plants (Fig. No. 48). Solutions of soda ash should be made or stored in iron tanks, as soda ash will attack concrete.

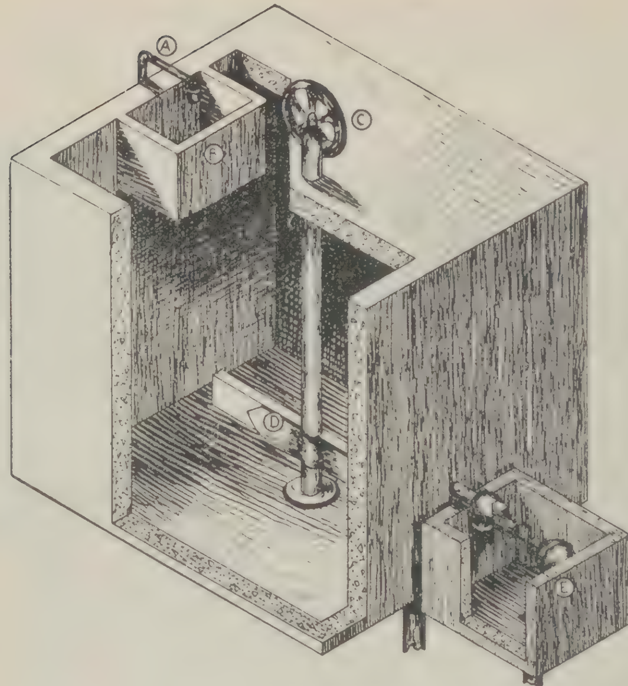


FIG. No. 47. Schematic representation of chemical solution tank. A—Spray pipe. B—Compartment for dissolving chemicals. C—Motor driven mixer. D—Paddles for stirring solution. E—Orifice box.

There should be two or more tanks provided for the preparation of chemical solutions. The tanks should be of such size that fresh solutions need not be made oftener than every twelve hours.

In the preparation of solutions, large amounts of the chemicals should not be placed directly in the water in the solution tanks. If this is done, considerable difficulty may be experienced in obtaining a proper solution, particularly in the case of soda ash which, when covered with water, tends to form an insoluble mass. This difficulty may be avoided by placing the chemical in a perforated compartment within and at the top of the solution tank and dissolving it under a spray, the resulting solution flowing through the perforations into the large tank below.

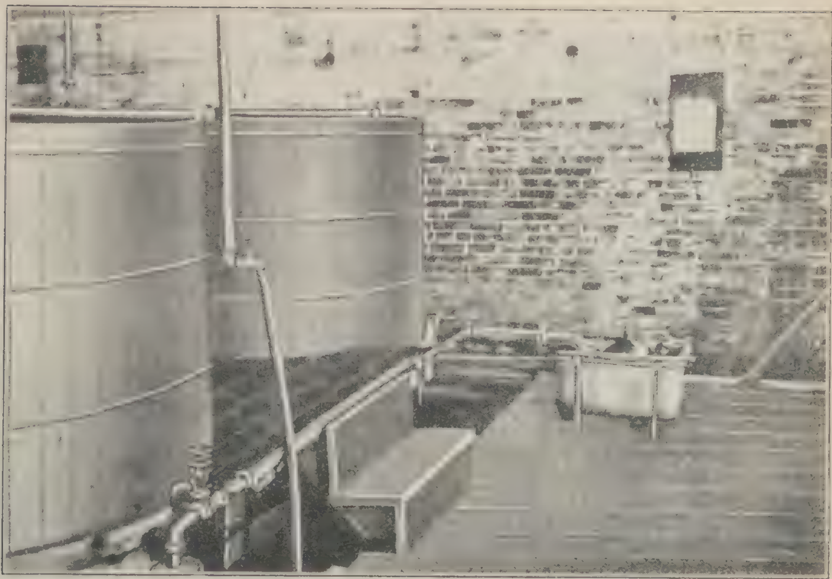


FIG. No. 48. Solution tanks and orifice box for applying alum. The alum solution flows from the orifice box directly into the mixing channels which are immediately below the floor.

In order to maintain a uniform strength throughout the solution, the tanks may be equipped with paddles on a vertical shaft which is rotated by an electric or water driven motor (Fig. No. 47).

The strength of the chemical solution being known and constant, the solution must be applied at a rate which is uniformly proportional to the flow of the water being treated. This is accomplished by means of an orifice tank or box (Figures No. 48 and 49), or by automatic devices of various kinds.

An orifice tank consists of an iron, concrete or porcelain lined tank in which the depth of the liquid or the size of the orifice can be adjusted either manually or automatically. The solution enters the orifice tank through a stop cock which is controlled by a float so as to maintain a uniform depth of the solution in the tank. If the depth of the fluid over the orifice is constant, the flow through the orifice is proportional to the area of the opening and the rate of flow can be varied by changing the size of the opening. Or, if the size of the opening is fixed, then the rate of discharge can be varied by raising or lowering the orifice in relation to the surface of the

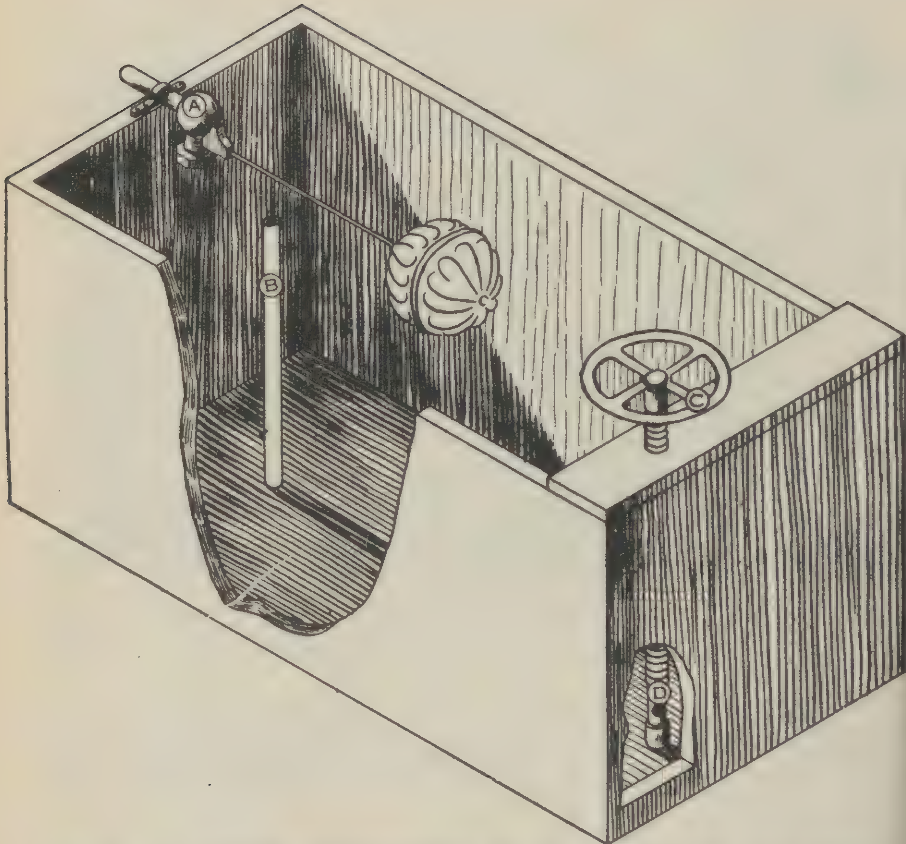


FIG. No. 49. Schematic representation of an orifice tank. A—Float control inlet valve. B—Overflow pipe. C—Hand wheel and stem for controlling depth of orifice. D—Orifice.

overlying fluid, thereby decreasing or increasing the depth of the fluid above the orifice. A hand wheel with a threaded stem is used to move a sliding or rotating disk which adjusts the size of the orifice, or to raise or submerge a vertical pipe in the side of which an orifice of fixed size is located.

The discharge from an orifice box may be automatically controlled by devices which are in turn governed by the rate of flow of the raw water. One such appliance utilizes the variations in pressure in a Venturi tube (page 276) to move floats, which by their movement adjust the size of an orifice so that the flow through the orifice is proportional to the flow of raw water.

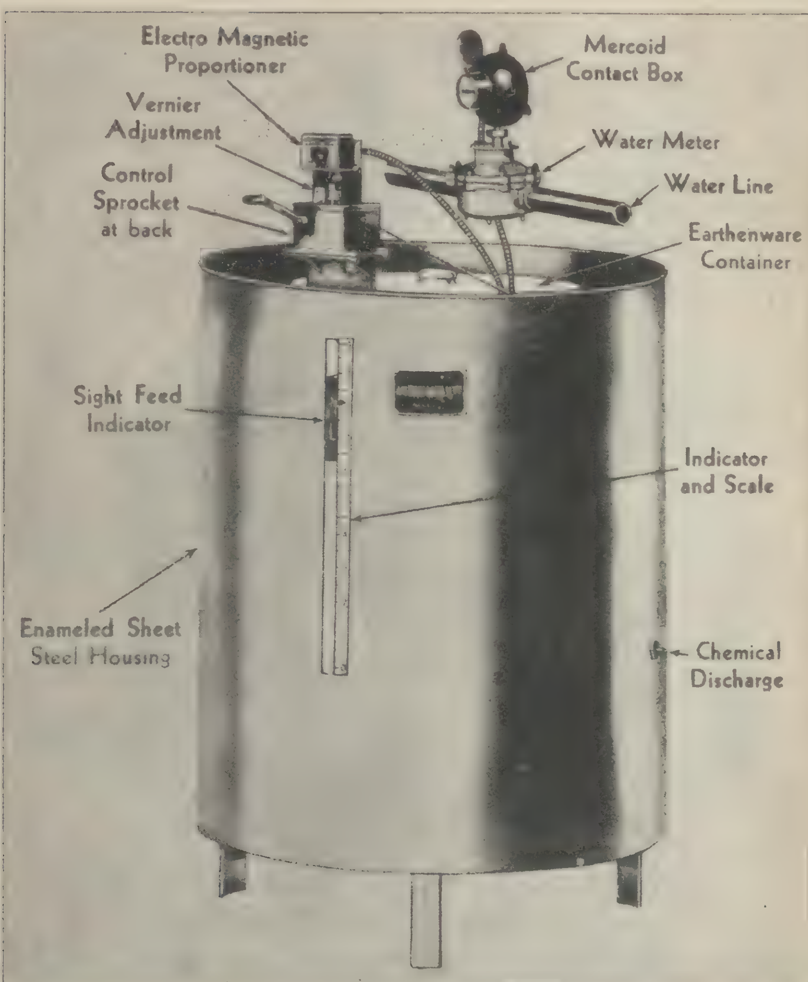


FIG. No. 50. Automatic solution feeder for applying chemicals in proportion to the rate of flow. (Courtesy of the American Water Softener Company, Philadelphia, Pa.).

Two types of automatic solution feeders are shown in Figures No. 50 and 51.

The solutions are conveyed by pipes directly from the orifice tank or feeder to the raw water. All piping used to carry alum solutions should be made of hard rubber, bronze, or lead. Iron pipes may be used for soda ash solutions.

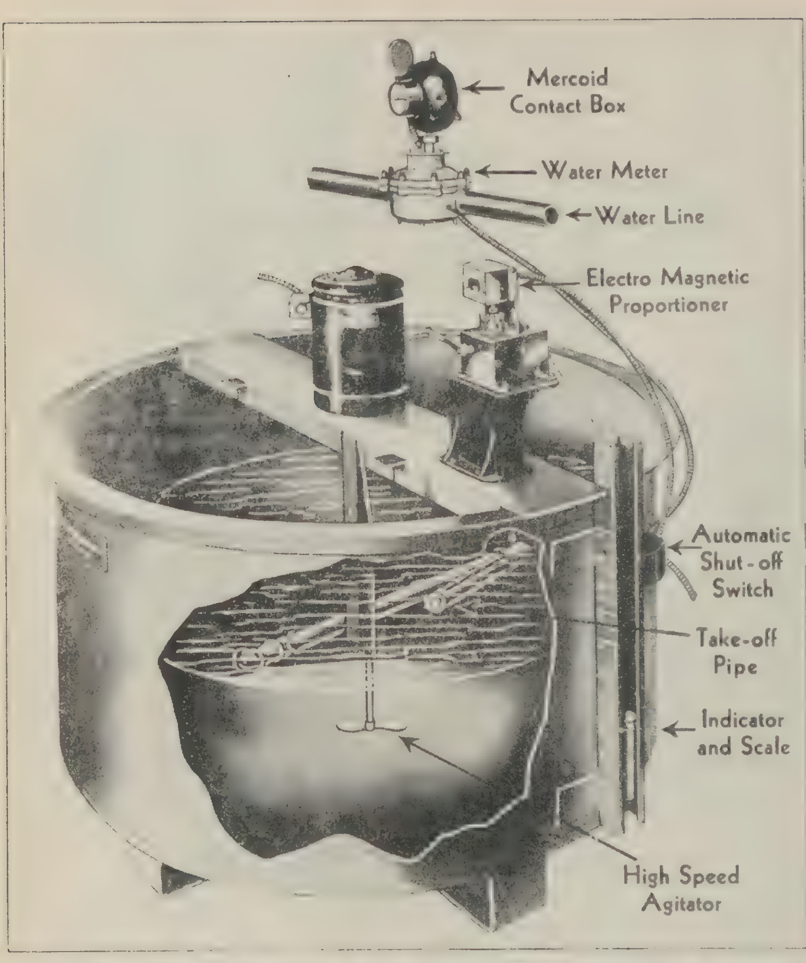


FIG. No. 51. Automatic solution feeder for applying chemicals in proportion to the rate of flow. (Courtesy of the American Water Softener Company, Philadelphia, Pa.).

Dry feeding (Fig. No. 52). Chemicals may be applied to the raw water in a dry state. The apparatus employed for this purpose usually operates by discharging the chemicals into flowing water by means of an automatic device. Two automatic feeders are shown in Figures No. 52, 53 and 54.

Control of rate of filtration. In order to obtain the best results in the removal of organic material by filtration, it is necessary to maintain a uniform rate of flow through the

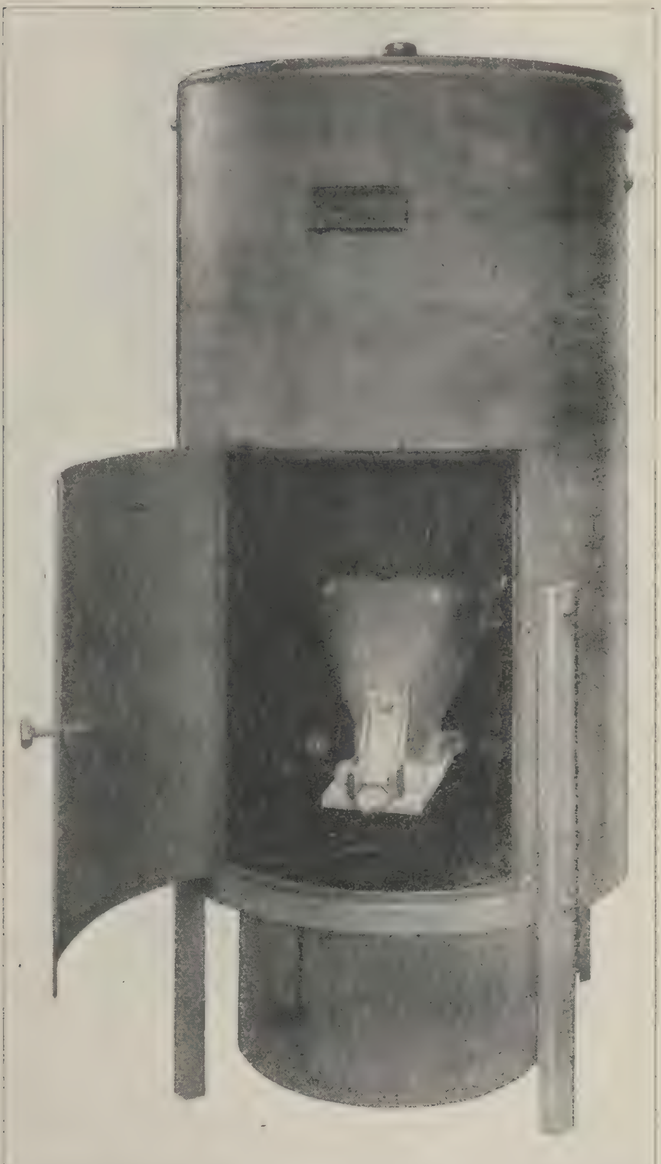


FIG. No. 52. Dry chemical feeder. The chemical is discharged in predetermined quantities through the oscillating feed spout which travels backward and forward across the feed slide. (Courtesy of the Wallace and Tiernan Co., Inc., Newark, New Jersey.).

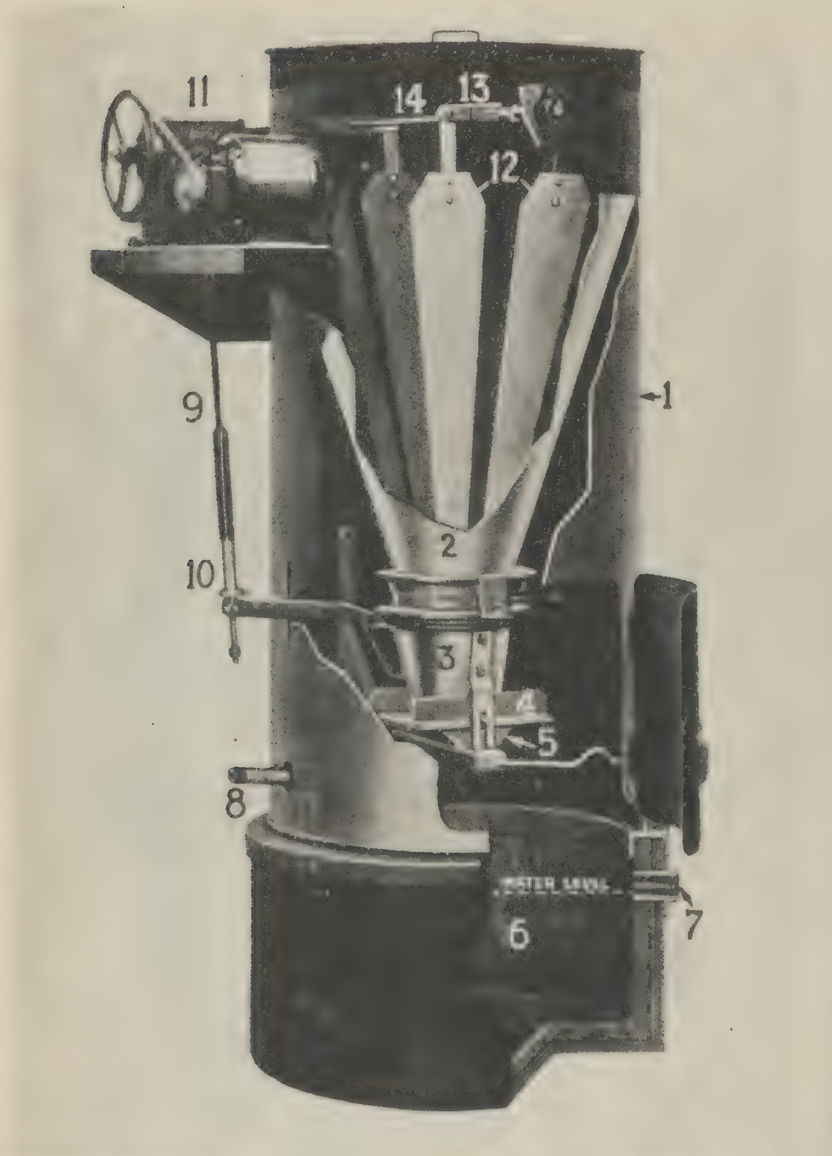


FIG. No. 53. The Omega universal feeder for the application of chemicals to water. The principal parts are:

(1) Housing
(2) Hopper
(3) Oscillating Hopper
(4) Scraper
(5) Receiving Tray
(6) Mixing Chamber
(7) Outlet
(8) Water Jet
(9) Connecting Rod
(10) Micrometer Screw
(11) Speed Reducer
(12) Agitator Plates
(13) Rocker Arms
(14) Agitator Shaft

(Courtesy of the Omega Machine Company, Kansas City, Missouri).

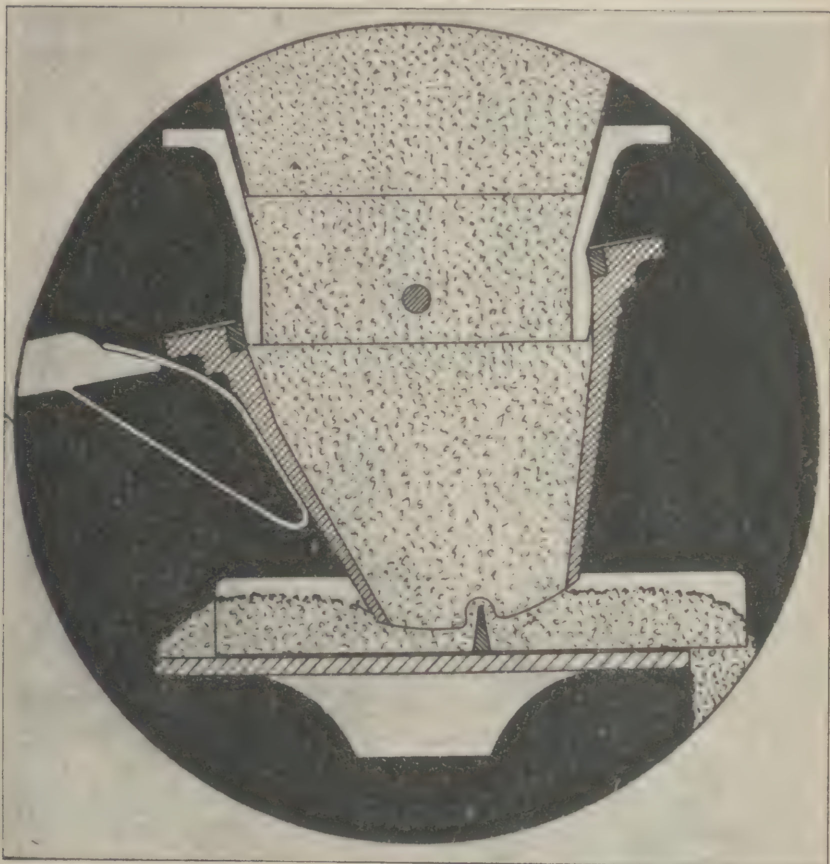


FIG. No. 54. Feeding device of the Omega Universal Feeder (Fig. No. 53). The width of the ribbon of chemical is fixed, but the depth can be changed to suit various conditions by raising or lowering the tray. The hopper oscillates back and forth and pushes a predetermined quantity of the chemical into the water with each oscillation. (Courtesy of the Omega Machine Company, Kansas City, Missouri.).

filter. Water will flow rapidly through a bed of clean sand, but as the interstices of the sand become clogged with retained organic matter, the frictional resistance to the flow of the water increases and the output of the filter gradually decreases. Sudden changes in the rate of discharge from a filter interfere with the process of filtration and purification. A sudden increase in the rate of flow through a filter may result in con-

taminated water being drawn through the filter. A sudden decrease in the rate is apt to release air which has been held in the filter by a high rate. The released air on rising to the surface of the filter will break the surface mat and produce areas through which contaminated water will escape into the underdrains.

When the loss of head has reached a point where the effluent valve must be fully opened in order to obtain the desired rate of flow, further loss of head will cause a reduction in the rate of flow. At this point it may be necessary to wash the filter, but in the operation of some plants, filtration may be allowed to proceed at a gradually decreasing rate until the loss of head prevents further efficient filtration. The filter must then be washed (page 258).

The rate of filtration is controlled by interposing in the effluent pipe of a filter a valve known as a rate controller, or effluent valve, which will create resistance to the flow and which can be so adjusted, either manually or automatically, as to produce a uniform rate of discharge. After a filter is washed the effluent valve is adjusted so that the discharge rate from the filter corresponds to the rate of filtration desired, usually 100 to 125 million gallons per acre per day. As the frictional resistance in the sand increases, a uniform rate is maintained by gradually opening the effluent valve and thus decreasing the resistance in the effluent pipe. Where the rate of filtration is manually controlled, the effluent valve is adjusted by hand levers. Automatic control is usually effected by means of floats or a Venturi tube.

The float controller consists of a float chamber so placed that the height of the water in the chamber varies with the rate of flow. The float is connected, by means of rods or levers, with a balanced valve in the effluent pipe. As the level of the water in the float chamber varies, the rising and falling of the float serves to close and open the valve and thus maintain a uniform rate of flow (Fig. No. 55).

The Venturi tube (Fig. No. 56). The Venturi tube is the most commonly used device for controlling the rate of flow. It consists of a pipe having a restricted portion known as the throat. As the water flows through the restricted portion, the velocity is increased and the pressure relatively decreased. The Venturi tube forms a part of the effluent pipe

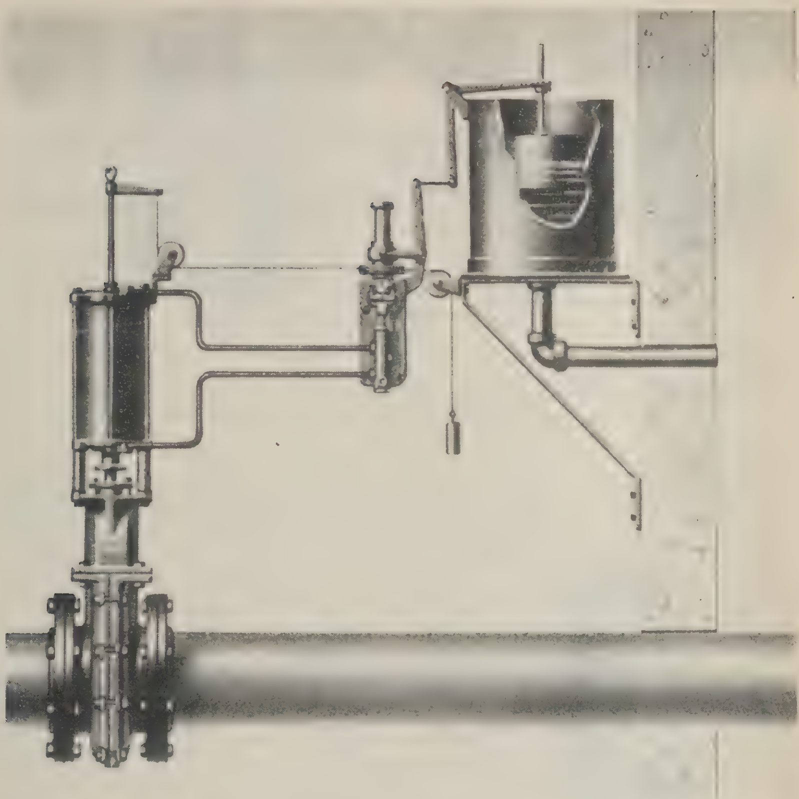


FIG. No. 55. Water level controller. The controller operates a hydraulic valve so as to maintain the water level in basin or reservoir within predetermined limits. (Courtesy of the International Filter Co., Chicago, Ill.).

line and the effluent valve is so placed in the pipe that the tube is between it and the filter. The valve is connected with the throat of the Venturi tube by means of a small pipe. The varying difference between the pressure in the throat of the tube and that existing in the pipe where the valve is placed operates a balancing mechanism which opens and closes the openings of the valve so that a constant rate of flow is maintained (Fig. No. 57).

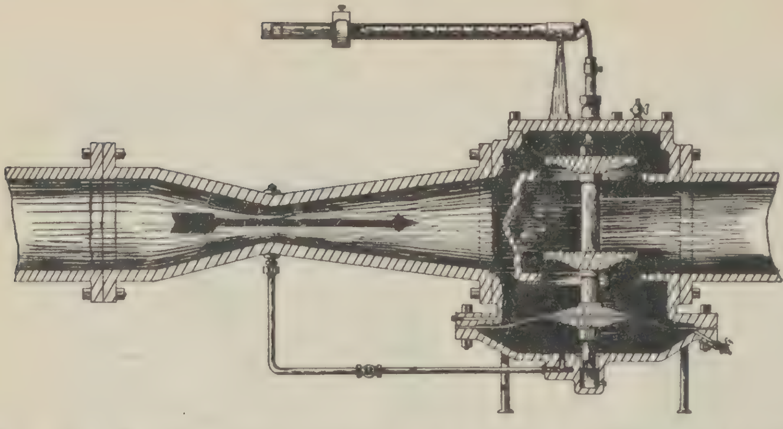


FIG. No. 56. Balanced rate controller valve actuated by variations in pressure in the Venturi tube (Schematic).

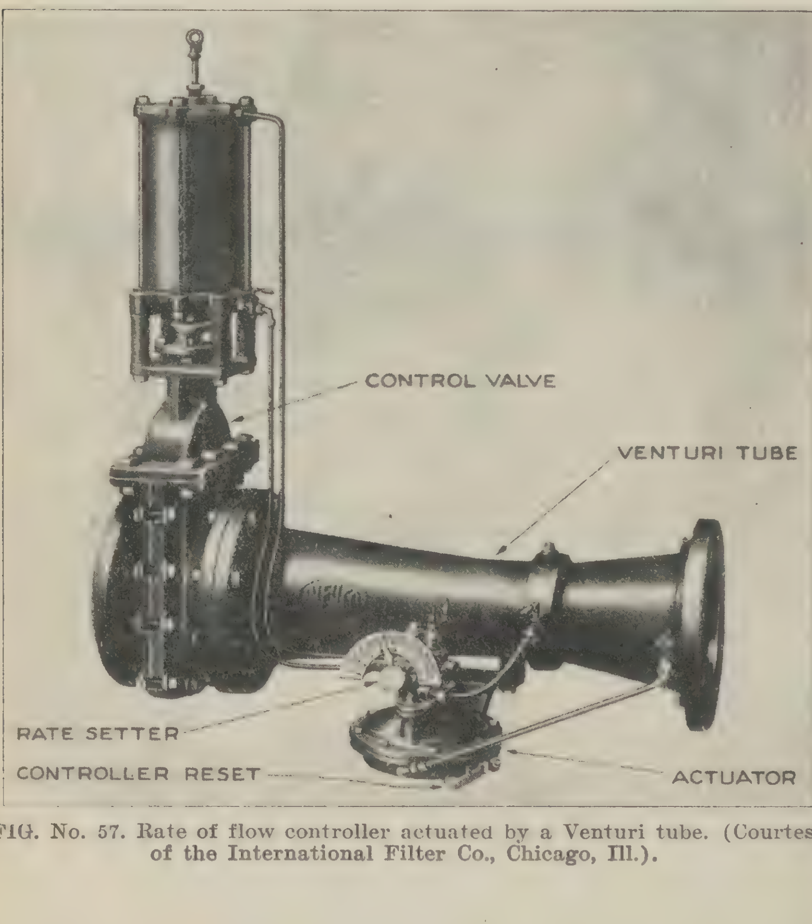


FIG. No. 57. Rate of flow controller actuated by a Venturi tube. (Courtesy of the International Filter Co., Chicago, Ill.).

Measuring devices. The efficient operation of a filter plant requires that the operator be able to determine the rate of filtration and the loss of head at any time. In plants where the rate of filtration is automatically controlled, dependence may be placed upon the control mechanism to maintain the desired rate but, ordinarily, a method of measuring the flow should be available.

The meter which is usually employed for determining the rate of filtration is governed by a Venturi tube in the effluent pipe (Fig. No. 58). If a Venturi tube is used to control the effluent valve, the same tube may be used in measuring the flow. Small pipes are connected with the pipe leading to or from the tube and with the throat of the tube. Variations in the pressure of the water in the tube and in the pipe are transmitted through the small pipes to the mechanism of a gauge, which when actuated by the difference in pressure, indicates on a dial the rate of flow in millions of gallons per acre per day. The Venturi tube may also be used to measure the rate of flow in wash water pipes and the main effluent line.

The loss of head (page 256) is usually determined by comparing the head (*pressure*) of the water on the filter at the surface of the sand with that in the effluent pipe. If a vertical tube or pipe is connected with the filter just above the surface of the sand, the water in such a tube will rise to the level of the surface of the water on the filter (Fig. No. 39). However, as the water passes through the filter, there is an increasing loss of head due to the frictional resistance of the sand so that the head of the water in the effluent pipe is correspondingly decreased. If a vertical tube is connected with the effluent pipe, the level of the water in this tube will be determined by, and vary with, the pressure in the effluent pipe, but will be lower than the level of the water in the tube connected with the water at the surface of the sand. The difference between the two levels, as expressed in feet, represents the loss of head. A counterweighted float may be placed in each of the two vertical tubes and connected with the mechanism of a loss-of-head gauge by means of cords. The movement of the floats serves to operate the gauge so that the dial shows the difference between the two levels, which is the

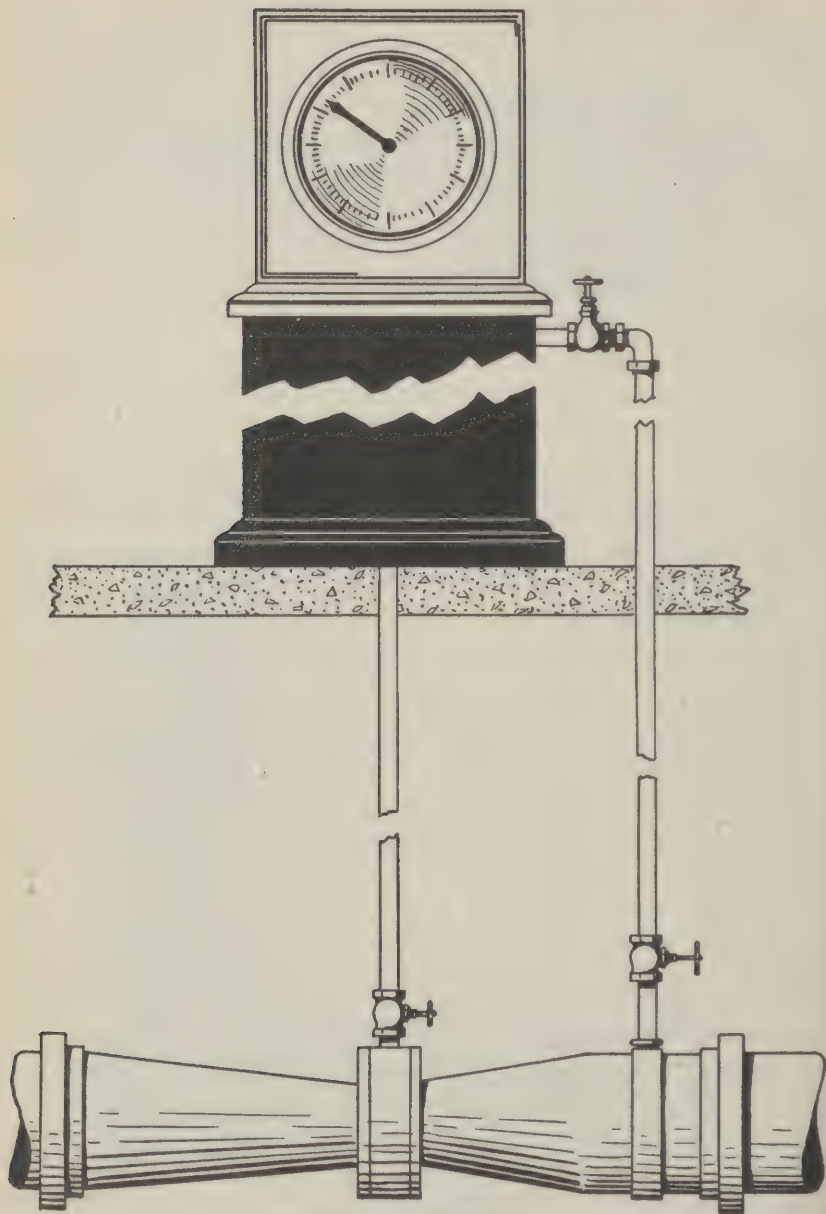


FIG. No. 58. Venturi meter for measuring rate of filtration (Schematic). Small pipes lead from Venturi tube to float chamber. Dial shows rate of flow through filter.

loss of head. Other gauges are governed by a mercury manometer connected with the water above the filter and that in the effluent pipe. A single pipe and float connected to the effluent pipe of the filter may be utilized to measure the loss of head.

Efficiency of the rapid sand filter. A rapid sand filter plant will remove practically any amount of turbidity, provided the water is properly coagulated and settled prior to filtration. Under ordinary conditions, it will remove from 97 to 99 per cent of bacteria contained in the raw water.

The rapid sand filter must be skilfully operated to prevent the occurrence of defects which will permit the passage of contaminated water. Faulty operation can be prevented only by frequent inspections and constant supervision.

Slow sand filter. In principle, the action of a slow sand filter is a close imitation of natural filtration of water through the soil. Primarily, it is designed to filter water which has not been subjected to any preliminary treatment or only to plain sedimentation. Consequently, the slow sand filter is used principally for the filtration of waters that do not contain large amounts of turbidity and are not subject to sudden additions of large quantities of suspended organic matter.

As the water passes slowly through the filter, a gelatinous film is formed on the sand grains (page 242) and a mat-like mass of the same material forms on the surface (*Schmutzdecke*), which entraps and retains the organic matter suspended in the water.

Rate of filtration. The rate of filtration through a slow sand filter is usually about three million gallons per acre of filter surface per day. A flow of three million gallons per acre per day is equal to approximately 69 gallons per square foot of filter surface per day, or 2.85 gallons per hour.

Construction of a slow sand filter. Because of the slow rate of filtration, a comparatively large amount of filter surface is required to filter a given quantity of water, and filter beds vary in size up to an acre in extent. The number of beds required for any one installation depends upon the maximum quantity of water to be filtered and the frequency with which beds must be placed out of service for cleaning.

The filter bed is a shallow, water-tight reservoir containing a layer of sand supported by a layer of gravel. Below the

gravel are underdrains for the purpose of draining away the filtered water (Fig. No. 59).

The filter bed may be built to conform to the contours of the ground, in which case it may be of any shape or size. Usually, however, the beds are rectangular or square in shape, with reinforced concrete, masonry or earth embankment walls and concrete or pavement bottoms. The filter basin may be elevated on groined arches with a filtered water basin underneath.

The filter beds may or may not be covered. Usually, they are covered, as a cover protects the water from freezing and also prevents the growth of algae with the consequent production of tastes and odors in the water. The roof may be flat or of groined arch construction. It is usually covered with several feet of earth with openings for the admission of light

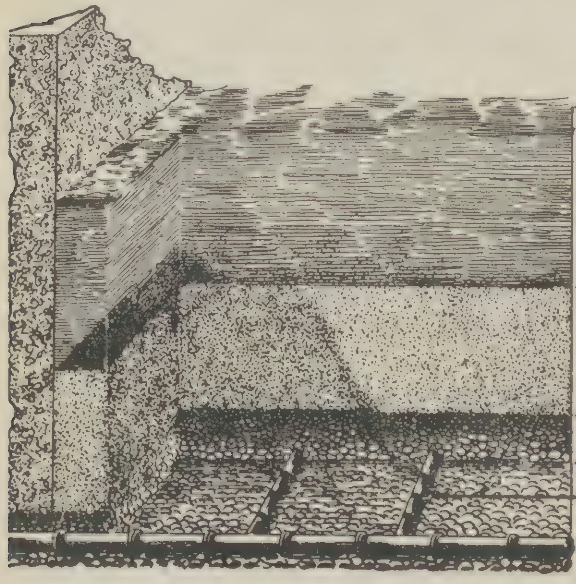


FIG. No. 59. (Schematic) Slow sand filter showing relation of sand, gravel and underdrains.

and air during the cleaning of the filter and, in some instances, for the introduction and removal of sand.

Each filter bed is an independent unit in order that it may be thrown out of service for cleaning or repairs without interfering with the operation of the remainder of the plant.

Leaks in the bottom of the filter may permit the entrance of contaminated ground water when the level of the ground water is higher than the water on the filters. If the level of the water on the filter is higher than that of the ground water, a considerable quantity of water may be lost by leakage through defective walls or bottom.

Underdrains (Fig. No. 59). The underdrains, or collecting system, consist of a central main drain into which lateral drains empty. The underdrains rest on the bottom of the filter basin or may be buried in the floor with their upper surfaces flush with or slightly above the surface of the floor.

The main drain is usually a water-tight tile or pipe, but may be constructed of brick or concrete. The lateral drains are usually of tile, smaller than the main drain, and laid with open joints to permit the entrance of water from the overlying filter. The lateral drains usually open into the main drain at right angles. The main drain conducts the filtered water into a clear water basin or well. It is essential that the frictional resistance to the flow and the velocities in the underdrains be properly distributed in order that the filtration will be uniform in all parts of the bed. The size and position of the underdrains in relation to the size of the filter and the rate of filtration are therefore important factors in the construction of the filter.

The gravel layer (Fig. No. 59). Above and surrounding the underdrains is a layer of gravel from 12 to 15 inches in thickness which supports the sand and prevents it from being carried by the water into the underdrains. In a slow sand filter, the gravel is graded so that the underdrains are surrounded by coarse stones, above which are successive layers of finer gravel until the sand is reached. The rock should be one of the harder varieties in order to avoid the disintegration which frequently occurs when rock such as limestone is used.

The sand layer. The sand is the true filtering medium, but little filtering action being effected by the gravel. The sand layer is usually about three feet in depth in a new or a freshly resanded filter. The process of cleaning the filter reduces the thickness of the bed and while, theoretically, a foot of sand is sufficient in so far as efficient filtering action is concerned, in practice the sand layer is seldom reduced below two feet in thickness. The excess depth of sand in a new

or resanded filter is for the purpose of permitting cleaning without immediate resanding.

The sand should be clean quartz containing but very small quantities of lime or magnesium. The effective size of sand used in slow sand filters varies from 0.2 to 0.4 millimeter with a uniformity coefficient of approximately two (page 254).

Sedimentation basins for slow sand filter. If the turbidity of the water admitted to a slow sand filter is too great, the filter will clog in a comparatively short time and there will be a rapid loss of head. Consequently, it is necessary in many instances to provide for pretreatment of the water. This is usually accomplished by means of sedimentation, either plain or subsequent to the addition of chemicals.

Sedimentation or settling basins for a slow sand filter are, as a rule, equipped with baffles to prevent cross currents and with drainage sumps to facilitate emptying and cleaning. The size of the sedimentation basins depends upon the quantity and turbidity of the water and whether the water is treated by plain sedimentation or coagulation. Plain sedimentation basins are usually much larger than those employed for coagulation of water.

Operation of slow sand filter. The depth of water on the filter varies, but is usually from three to four feet. When water containing but little organic matter is placed on a clean filter it will, if uncontrolled, pass rapidly through the sand and but little filtering action will occur. If, however, the rate of flow through the filter is controlled, organic matter is retained in the upper layer of sand, where it forms a gelatinous film on the sand grains and eventually produces the surface mat. As in the operation of the rapid sand filter, the deposited organic material increases the frictional resistance to the flow of water through the sand, and, within certain limits of too little and too much frictional resistance, filtration of the water takes place. The frictional resistance of the sand and, therefore, the filtering efficiency of the filter are measured by the loss of head resulting from the passage of the water through the sand. When the loss of head amounts to from four to five feet, it is usually necessary to clean the filter.

Control of the rate of filtration. In the operation of a slow sand filter, control of the rate of filtration is most im-

portant. The efficiency of the filter depends upon the slow passage of the water through the sand, giving time for the suspended organic matter, including bacteria, to adhere to the gelatinous material on the sand grains and in the surface mat. The flow of water through the sand, particularly the upper part of the sand layer, must be uniform and of such low velocity that organic matter is not displaced and carried through the filter.

If the velocity of the water is not decreased by artificial means, the water will pass through comparatively clean sand at a rate which is far too rapid to permit satisfactory filtering action. Consequently, it is necessary to interpose resistance to the flow at the outlet of the filter. In order to maintain a uniform flow, the resistance at the outlet must be considerable while the filter is clean, and must be gradually reduced as the frictional resistance to the flow of water through the sand layer is increased by the clogging of the sand with organic matter. Many devices have been used for maintaining a uniform flow and most of them depend upon blocking in some manner, either manually or automatically, the flow of water from the effluent main. They consist of valves in the effluent main which, in the more modern plants, are controlled by the Venturi tubes or movable weirs (page 276). In practice, the resistance interposed by any one of these devices is gradually decreased as the frictional resistance within the filter increases.

In some filters it is also necessary to control the flow of water onto the filter. This is usually accomplished by means of a float on the surface of the water in the filter which operates a valve in the influent line. If the velocity of the water as it enters the filter is too high, the surface of the sand bed will be disturbed, with a consequent loss of filtering efficiency.

Methods of cleaning the filter. When the loss of head reaches a point where the filtering efficiency is decreased, the filter must be cleaned. The length of time which a filter will function properly without cleaning depends upon a number of factors, such as the turbidity of the raw water, the rate of filtration, or the temperature. This period may vary from a few days to several weeks, the average being about three or four weeks. As the loss of head is due to increased fric-

tional resistance caused by the organic matter deposited on the surface and in the upper part of the sand bed, cleaning consists of removing a thin layer of sand, together with the surface mat, from the sand bed.

When a filter is to be cleaned the influent valve is closed and the water drawn off through the filter, either completely or until it is well below the surface of the sand. From one-half to one and one-half inches of sand are removed from the surface by means of broad flat shovels. Usually, the sand is piled in heaps on the filter bed to be removed later, either by portable sand ejectors, in which the sand is carried by water under pressure through pipes, or by wheelbarrows to a point outside the filter where it is washed. The dirty sand is washed in hoppers so constructed that the sand falls through an upward flowing current of water. The organic material, being lighter than the sand, is carried away by the water. The clean sand may be stored in bins or used immediately to resand a filter bed.

When the dirty sand has been removed, the surface of the bed is smoothed, the filter is filled with raw water and filtration started. The water passed through a clean filter is wasted until bacteriological and physical tests of the filtered water show that filtering efficiency has been restored.

Resanding. The cleaning process is repeated a number of times without returning the sand to the filter until the depth of the sand bed is reduced by a foot or more, or to a depth of from 18 to 24 inches. When this occurs, the filter is given a final cleaning, when possibly several inches of sand are removed, and resanded by adding sand until the sand bed is restored to its original thickness. Ordinarily, the sand is carried from the clean sand bins through ejectors and hose lines onto the filter bed over which it is distributed by attaching the hose lines to rafts or boats floating on the water above the surface of the sand. When the desired depth of sand has been attained, the water is drawn down and the surface of the sand smoothed. The filter is then ready to start.

The sand may be carried onto the filter in wheelbarrows and spread by hand. The clean sand should be placed in uniform layers on the surface of the filter.

Emergency cleaning. At times, the character of the water may be such that a filter will clog rapidly, necessitating

frequent cleaning, and the time required for the usual cleaning methods will seriously reduce the capacity of the plant. Under such circumstances, one of two emergency measures may be employed to keep the filter in service. These are raking, or scraping and piling.

The filter may be partially drained and the surface of the sand raked with short-toothed garden rakes. This breaks up the surface mat and loosens the upper part of the sand bed. The filter can be started immediately. As a rule, raking can be repeated only once, after which the filter must be thoroughly cleaned.

The surface of the filter may be scraped in the usual manner and the sand placed in piles on the surface of the sand bed. However, instead of removing the sand to be cleaned, the piles are left in place and the filter started. The piles do not interfere with the filtering action of the filter, except in so far as they decrease the available filter surface, and the time required to move the sand from the filter is saved.

Efficiency of slow sand filters. The efficiency of the slow sand filter in the removal of bacteria and turbidity depends to a considerable extent on the character of the raw water. This type of filter is most efficient in the filtration of water having less than 50 parts per million of turbidity. Higher turbidities necessitate the addition of a coagulant, or the use of prolonged sedimentation prior to filtration, in order to remove the sediment which would otherwise clog the filter and render frequent cleaning necessary.

Given a suitable raw water, properly controlled and supervised slow sand filters will remove from 97 to 99 per cent of the organisms originally present in the raw water. However, as the small percentage that remains may include disease-producing organisms, it is usually necessary to chlorinate the filtered water.

The slow sand filter is more expensive to install and it requires much more space than a rapid sand filter. The cost of operation is greater for the rapid sand filter than for the slow sand filter, due to the fact that chemicals must be used and a greater amount of labor is required in the operation of the rapid sand filter. As compared with the rapid sand filter, the failure of the slow sand filter to clarify water of moderate turbidity, and the larger space required for installation,

limit its usefulness in the military service. Consequently, a slow sand filter is seldom utilized to supply water for troops, except where it is owned and operated by a civilian agency.

Pressure filter. The pressure filter is a rapid sand filter to which water is applied under pressure. The principles involved are the same as those concerned in the construction and operation of the gravity type of rapid sand filter. Usually, the pressure filter is employed only in the purification of small water supplies or where conditions are such that a gravity filter cannot be used (Fig. No. 60).

The pressure filter unit consists of an upright or horizontal closed steel or iron cylinder containing a layer of sand and a layer of gravel, and equipped with underdrains to collect the filtered water. Each unit has valves corresponding to those used on a gravity rapid sand filter, that is, influent, effluent, drain, filtering to waste, and wash water valves (page 265).

The filter unit is placed between the pumps and the service mains or clear water basins. The water is pumped onto the top of the sand layer and forced through the filter by pressure. Where the water is pumped directly from the source of supply to the filter, the necessary chemicals consisting of alum, soda ash, and in some instances, chlorine and ammonia are applied to the water in the suction line leading from the pump to the source of supply. If the water is pumped from settling basins, the methods of applying the chemicals may be the same as those used in the operation of a gravity filter. The chlorine solution may be added after filtration by injection into the discharge pipe or by gravity to the water in a clear water basin or well.

The filter is washed in the same manner as a gravity filter, except that in some installations the sand is mechanically agitated with a hand agitator (page 258). Where no provision is made for the sedimentation of the coagulated water, the filter must remove all the floc and, consequently, the period between washings is usually much shorter than with a gravity filter.

The defects in the operation of a pressure filter which may be causes of contaminated water reaching the distributing system are, in general, the same as for a gravity filter (page 261). The pressure filter is not ordinarily as efficient as the gravity filter.

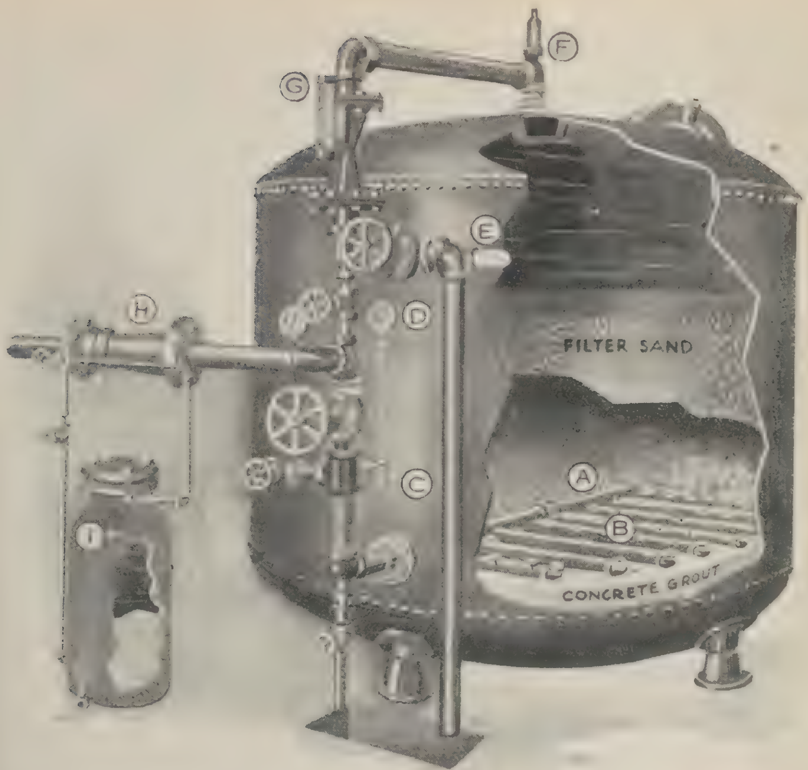


FIG. No. 60. Pressure filter. A—Gravel layer. B—Strainers (underdrains). C—Sampling cocks. D—Gauges. E—Observation glass. F—Automatic air relief. G—Flow indicator. H—Venturi proportioner. I—Coagulant tank (alum pot). (Courtesy of the International Filter Co., Chicago, Ill.).

CHLORINATION

There is no method of artificial purification of water by either biological or mechanical methods which, under working conditions, will remove or destroy all of the bacteria. The most efficient filters will permit the passage of from one to two per cent of the organisms present in the raw water and, in heavily contaminated waters, this small percentage may contain large numbers of pathogenic bacteria. Purification by storage and sedimentation can seldom be sufficiently prolonged, nor can the water be sufficiently safeguarded against recontamination, to insure the absence at all times of all pathogenic bacteria from the purified water. Consequently,

in order to destroy all of the pathogenic bacteria in water it is necessary to disinfect the water. The application of a disinfectant may be a final treatment subsequent to other purification procedures, or it may be the only treatment where the employment of other measures is not required or is not practicable. The disinfectant universally used in the military service in the purification of water is chlorine, either in the form of liquid chlorine or as calcium hypochlorite.

Reaction of chlorine in water. The chlorine combines with the water forming dilute hypochlorous acid and other chlorine compounds with the formation of nascent oxygen. Certain of the organic and mineral substances in the water are oxidized. Chlorine compounds are formed by the direct chlorination of organic matter. There are two theories relative to the bactericidal action of chlorine. The first and the oldest of these two theories is to the effect that the bacteria are destroyed by the nascent oxygen resulting from the decomposition of the hypochlorous acid. The second and more widely accepted theory is that the chlorine and chlorine compounds have a direct toxic effect on bacteria.

Chlorine demand. When the solution of chlorine gas or calcium hypochlorite has been diffused throughout the water, the resulting compounds having disinfecting value are known as free chlorine. When the ammonia-chlorine process (page 305) is used the most widely accepted theory is that the chloramines release free chlorine, and the amount of chlorine present in the form of chloramines is regarded as free chlorine. The amount of free chlorine which the organic and mineral matter in the water can absorb is the chlorine demand of the water in question. The chlorine demand varies with the quantity and character of the organic matter. If the chlorine demand of the organic matter is unsatisfied by the amount of free chlorine added to the water, the disinfecting action will be incomplete and not all of the bacteria will be killed. Therefore, the disinfection of turbid water requires a comparatively larger quantity of free chlorine than is necessary in the case of clear water in order to satisfy the chlorine demand of the organic matter, and thus insure that all the bacteria present are brought in contact with the chlorine.

Residual chlorine. When the chlorine demand is satisfied the excess chlorine remaining in the water constitutes

the residual chlorine. Theoretically, if sufficient chlorine is used, the chlorine demand of water is satisfied without appreciable delay after the application of the chlorine. However, in water purification practice it is customary, in order to provide a margin of safety, to allow the chlorine to act for a predetermined length of time, known as the *contact period* (*infra*). At the end of the contact period there should be remaining in the water, as shown by the orthotolidine or starch iodide test, at least 0.2 p.p.m. of residual chlorine in the form of free chlorine or chloramines.

Contact period. The effectiveness of chlorine as a disinfectant of water is measured by its lethal action on the coliform group of organisms, as determined by laboratory tests. Theoretically, pathogenic bacteria from the intestinal tract of man and *Escherichia coli* (*B. coli*) are killed on contact with chlorine. Using this theory as a basis, it was formerly assumed that the presence of residual chlorine in water after the chlorine demand had been satisfied indicated that all pathogenic bacteria had been killed. However, studies made by a number of different workers during recent years have demonstrated that under certain conditions the velocity of disinfection may be considerably reduced and that a longer contact period is necessary to effect complete disinfection. Disinfection is delayed in the presence of chloramines and by low temperature of the water. In waters having high pH values, disinfection is likewise delayed, especially where the residual chlorine is present in the form of chloramines (page 306). Apparently, small quantities of residual chlorine, less than 0.2 p.p.m., are less effective and necessitate longer contact periods than larger amounts. Also, there is evidence that some strains of the organisms concerned are more resistant than others to the lethal effects of chlorine.

In the chlorination of water having a low turbidity, a pH value of not more than 8.0 and temperature of not less than 20°C., a contact period of not less than ten minutes should be allowed, provided chlorine alone is applied. Where the ammonia-chlorine process is used and the residual chlorine is present as chloramines, the contact period should be at least twenty minutes. In the treatment of turbid water, or water having a high pH value or a temperature below 20°C., the contact period should be increased to thirty minutes.

Where water is chlorinated in water sterilizing bags (page 341) it is seldom possible to determine the characteristics of the water with regard to pH value and organic content. Here a contact period of thirty minutes should always be allowed.

Liquid chlorine. Chlorine is a gas which is readily liquefied by pressure and which returns to its natural gaseous state when released from pressure. Liquid chlorine, as ordinarily prepared for water purification work, is placed in steel cylindrical tanks about four feet in length and nine inches in diameter. Usually, each cylinder contains either 100 or 150 pounds of the liquid chlorine. The pressure within the cylinder, which varies from 40 pounds in cold weather to 150 pounds in hot weather, forces the chlorine to remain in the liquid form.

Calcium hypochlorite. Chlorinated lime (*bleaching powder, calcium hypochlorite*) is prepared by saturating slaked lime with chlorine gas. The resulting compound is a mixture of calcium salts, the active agent of which is calcium oxychloride. When dissolved in water, the calcium oxychloride forms calcium hypochlorite and calcium chloride. The calcium hypochlorite reacts with the carbonic acid in the water to form calcium carbonate and hypochlorous acid. The hypochlorous acid is decomposed into hydrochloric acid and other chlorine compounds and oxygen.

The strength of chlorinated lime is stated in terms of "available chlorine" present. The ordinary chlorinated lime when freshly prepared contains about 35 per cent of available chlorine. It deteriorates rapidly on exposure to air and tends to lose its available chlorine in a short time. When air tight containers are used, deterioration occurs more slowly, the available chlorine being lost under average conditions at the rate of about one per cent per month.

Calcium hypochlorite compounds are now available which have a higher chlorine content than the chlorinated lime. These compounds are known as *Grade A calcium hypochlorite* and include such products as HTH (high test hypo) and Perchloron. They have an available chlorine content of from 60 per cent to more than 70 per cent and are much more stable than the ordinary chlorinated lime. They are also more soluble and produce less sludge than the chlorinated lime.

Calcium hypochlorite is soluble in water in proportion of one part in twenty parts of water by weight. The chlorinated lime

contains ingredients such as calcium hydroxide and silica, which are relatively insoluble. These substances appear in the solution as a white precipitate which settles out as sludge.

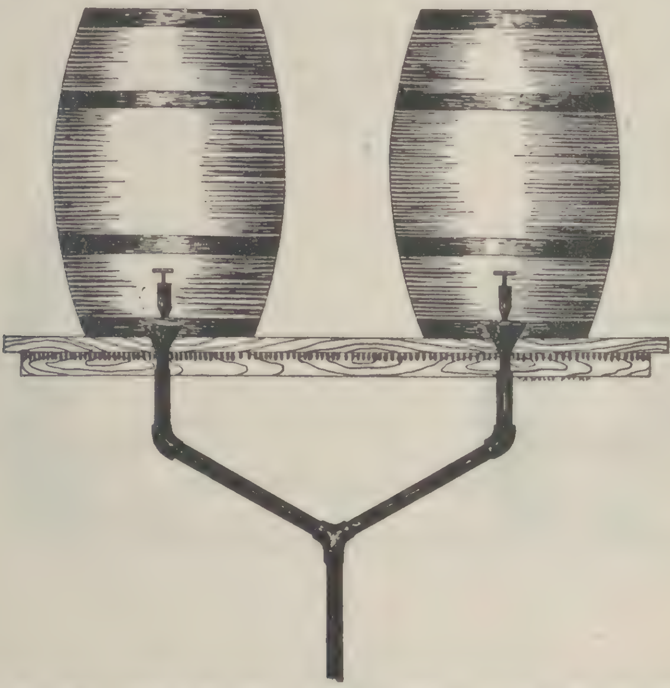


FIG. No. 61. Improvised chlorinator for applying calcium hypochlorite solution.

Application of chlorine and chlorine compounds. The amount of chlorine applied to water is stated as parts per million (p.p.m.), that is, the number of parts of chlorine in one million parts of water. One part per million of free chlorine is obtained by adding 8 1/3 pounds of liquid chlorine to one million gallons of water. The amount of calcium hypochlorite required to give one part per million of chlorine depends on the chlorine content of the hypochlorite. If *high test hypo* (HTH), or Perchloron, containing 65 per cent of available chlorine, or a similar compound, is used, about twelve pounds will be required to yield one part per million of free chlorine. If chlorinated lime having about 33 per cent of available chlorine is used, then twenty-five pounds in one million gallons of water will give one part per million of free chlorine. The quantity of

chlorine required for the purification of water varies from 0.1 to 2.0 parts per million, depending upon the chlorine demand of the water. However, as a matter of safety, the quantity of chlorine applied to the water should be such that at the end of the contact period, from 0.2 to 0.5 parts per million will remain in the water as residual chlorine. While, theoretically, if any measurable amount of residual chlorine is present it indicates that the water is adequately chlorinated, nevertheless, there should be a minimum of 0.2 p.p.m. in order to insure complete bacterial disinfection.

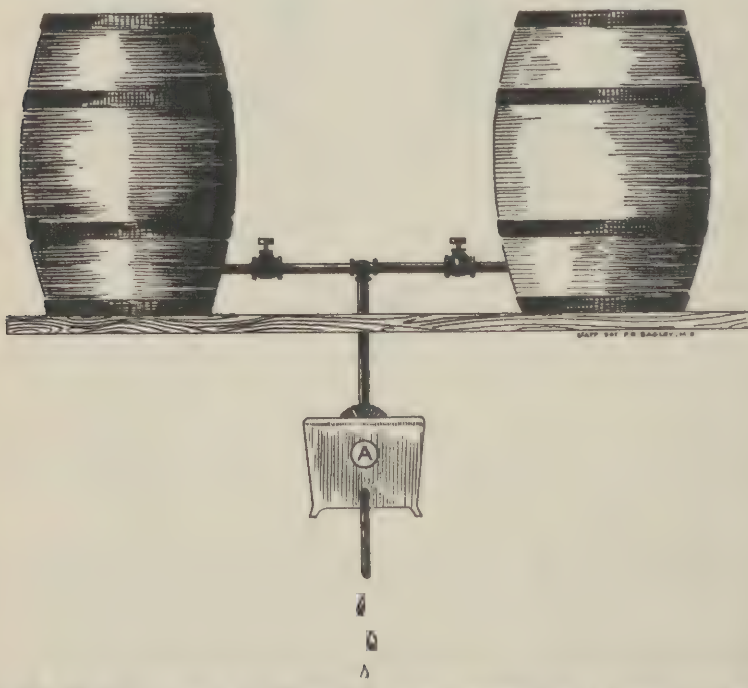


FIG. No. 62. Improvised chlorinator for applying calcium hypochlorite solution. A—Orifice box.

Calcium hypochlorite. If dry chlorinated lime is added to comparatively large quantities of water, there is a tendency for lumps to form which do not readily dissolve. Consequently, a preliminary solution must be made, and this solution must be prepared with care if satisfactory results are to be attained. The dry chemical is gradually worked into a smooth paste with small quantities of water, in proportions of about one pound of

the chemical in one gallon of water. The paste is then thoroughly mixed with water in proportion of about one gallon of the paste to ten gallons of water. After mixing, the insoluble portions of the chemical are allowed to settle out as sludge leaving a more or less clear supernatant liquid which contains the chlorine and chlorine compounds in solution. This solution is applied to the water being treated at a rate which will give the desired quantity of residual chlorine.

The *high test hypo* or *Perchloron* can be dissolved directly in water to make the final solution, but more satisfactory results are obtained if a preliminary solution is made by dissolving the chemical in a relatively small quantity of water and allowing the sediment to settle. The clear supernatant liquid is then diluted to the desired strength.

In the operation of water purification plants the preliminary solution is made in a mixing or pasting tank from which it passes into a solution tank (Fig. No. 47). A mixing tank is essential if chlorinated lime is used but is not always necessary where HTH or Perchloron is employed. The tanks should be made of concrete and the piping of pure wrought iron or lead. Corrosion and incrustation occur in cast iron pipes. Tile, lead, hard rubber and acid-proof bronze are not affected. Wood is attacked by solutions of calcium hypochlorite unless it is painted with asphaltum or mineral bituminous paint.

Where a mixing tank is utilized it is usually located above the solution tank and is equipped with overflow openings so that the paste can be flushed with water into the larger tank below. From the solution tank the solution flows into an orifice box or a solution feeder by which the rate of application is controlled. The solution tank should have a valved opening in the bottom connected to a drain pipe through which the sludge can be drained from the tank. The outlet for the solution should be above the sludge line.

In the operation of permanent or semipermanent installations the solution of calcium hypochlorite should be applied to the water by means of a solution feeder, or chlorinator. A number of different kinds of solution feeders are available and can be purchased. One such apparatus is shown in Figures No. 63 and 64.

The chlorination of temporary water supplies with calcium hypochlorite may be accomplished by the use of impro-

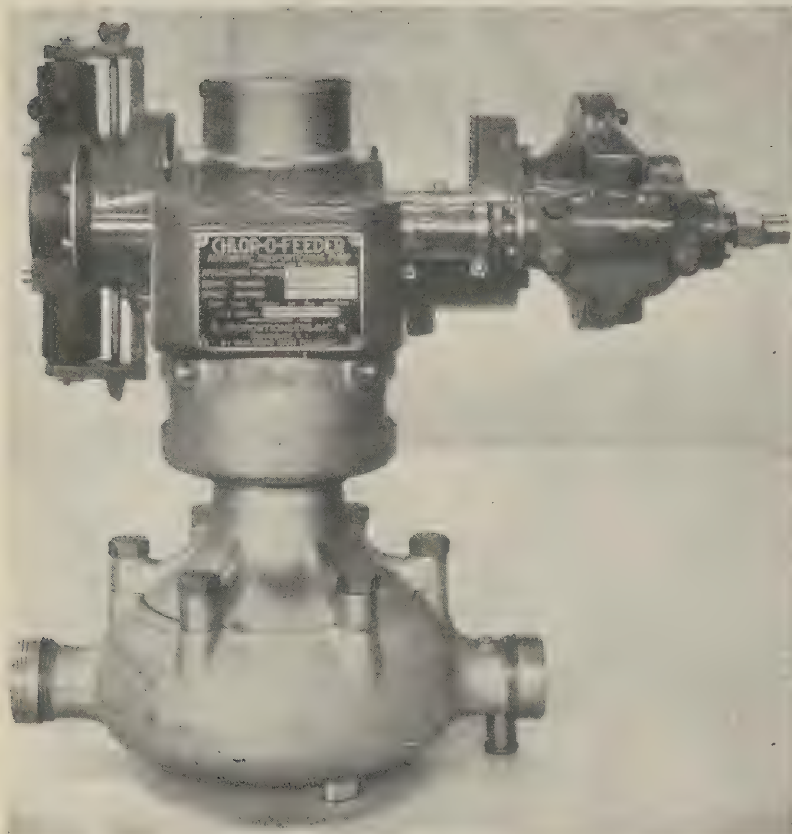


FIG. No. 63. Apparatus for the application of calcium hypochlorite solution in quantities proportional to the flow of water. This device is actuated by a water meter. See Fig. No. 64. (Courtesy of %Proportioneers%, Inc., Providence, R. I.).

vised apparatus, such as that shown in Figures No. 61 and 62. A wooden barrel may be used as a combined mixing and solution tank. Where continuous application is necessary, the barrels should be in duplicate so that one can be used as a chlorinator while a solution is being prepared in the other. The flow can be controlled by a wooden spigot, but, if practicable a solution feeder or an orifice box should be employed (Figures No. 65, 66 and 67).

Wooden barrels tend to deteriorate in a comparatively short time and, consequently, concrete tanks are desirable if the plant is to be used for any considerable length of time.

FIG. No. 64. See Fig. No. 63. Apparatus in operation. The calcium hypochlorite solution is in the glass jar in the foreground. (Courtesy of %Proportioneers%, Inc., Providence, R. I.).

Liquid chlorine. Liquid chlorine is applied by means of a chlorinator which acts as a regulator in controlling the rate of application and as a meter for measuring the quantity. The chlorine is confined as a liquid in a steel cylindrical tank under pressure which varies with the temperature, with the amount of chlorine in the tank and with the rate at which it is released.

FIG. No. 65. Apparatus with floating orifice for applying calcium hypochlorite solutions. Gravity feed.

(A) 2″ x 2″ piece of board of such length as to float freely in barrel.
(B) 4″ x 4″ piece 6″ long.
(C) Rubber stopper.
(D) 8″ Glass tube with orifice tip.
(E) ½″ Rubber tubing.
(F) ½″ Wood or hard rubber cock.
(G) 1″ Bored hole.
(H) Inlet to orifice.
(Courtesy of the Pennsylvania Salt Manufacturing Co., Philadelphia, Pa.).

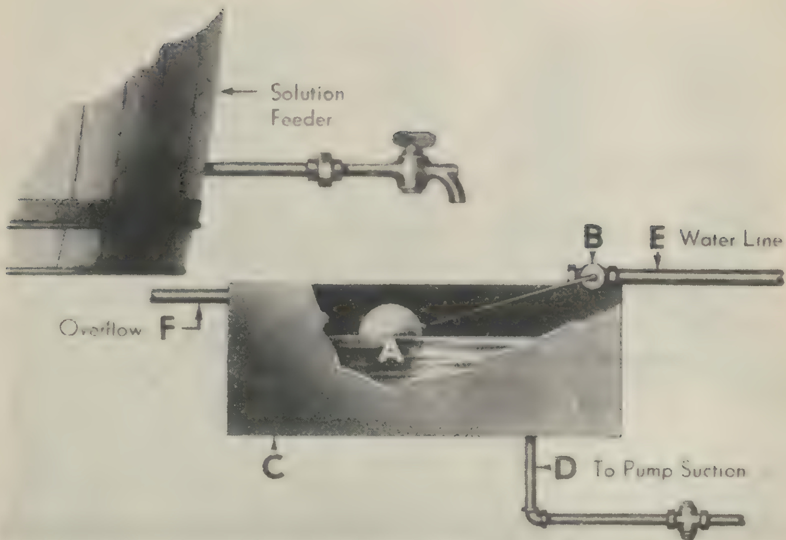


Fig. No. 66. Apparatus for applying calcium hypochlorite solution in a suction line. The small constant level tank prevents air from being drawn into the pump.
(A) Hard rubber float.
(B) Float valve.
(C) Wooden box.
(D) Hard rubber ¼" pipe and cock.
(E) ¾" st'd. pipe.
(F) ¾" st'd. pipe.
(Courtesy of the Pennsylvania Salt Manufacturing Co., Philadelphia, Pa.).

The function of a chlorinator is to feed the chlorine gas into the water at a given predetermined rate regardless of pressure in the chlorine tank.

The solution type chlorinator (Figures No. 69 and 70) consists essentially of a device for mixing the gas with water, and a meter. A solution of the chlorine gas is made in the chlorinator and is fed from the chlorinator into the water. In the ordinary chlorinator, the gas passes from the tank through reducing valves, and through a manifold if more than one tank is being used, to a compensator by which a uniform pressure in the gas line is maintained. From the compensator the gas goes through a chlorine control valve which controls the rate of flow into a solution jar. In the solution jar, the gas is mixed with water. With the gravity feed types where the chlorine solution passes into a reservoir, or a suction line, it flows from the solution jar

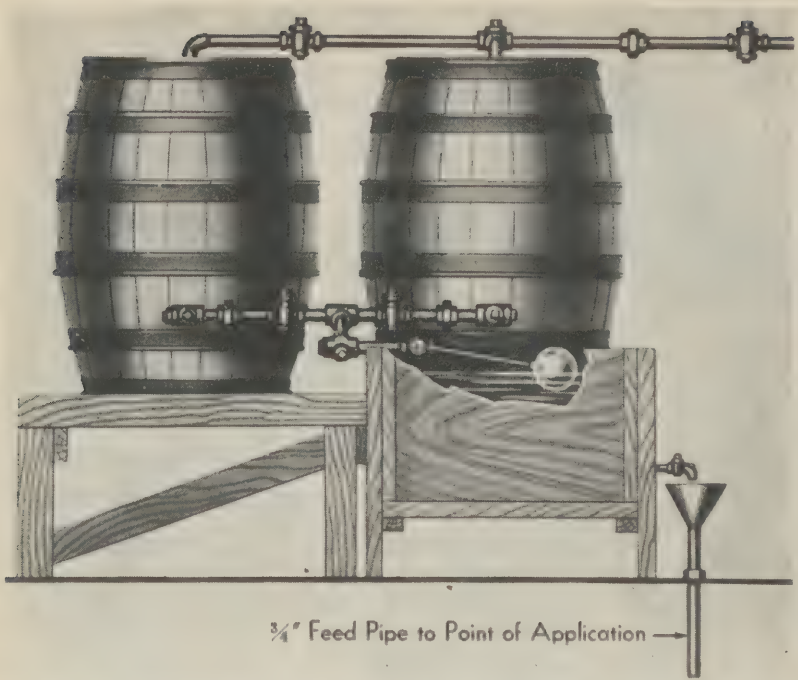


FIG. No. 67. Apparatus with orifice box for applying calcium hypochlorite solutions. (Courtesy of the Pennsylvania Salt Manufacturing Co., Philadelphia, Pa.).

through the solution hose to the point of application. If the solution is to be fed into a pressure main, an injector is used.

The dry chlorine gas may be applied to the water by means of a chlorinator which feeds the gas through a diffuser (Figures No. 73 and 74). The dry feed chlorinator has the advantage that no water supply under pressure is required for its operation.

Volatilization of liquid chlorine is inhibited or prevented by temperatures of less than 50° F. Consequently, the room in which the chlorinator and the tanks are housed should be kept warm and the temperature should not be allowed to fall below 50°F. If more than 40 pounds of chlorine are drawn from one tank during any one day the fall in temperature within the tank will be sufficient to interfere with volatilization.

Where practicable, duplicate chlorinators should be installed, so that chlorination will not be interrupted for repairs or adjustments. Duplicate parts of the chlorinator should be kept on hand so that repairs may be quickly completed.

FIG. No. 68. Improvised chlorinating apparatus for applying calcium hypochlorite solution. Chlorinator consists of three barrels.

The solution of chlorine, either of the chlorine gas or the calcium hypochlorite, must be well mixed with and diffused through the water in order that it may come in contact with all the organic material. The chlorine may be applied prior or subsequent to filtration. When the chlorine is added to the water before filtration, the process is known as pre-chlorination. The application of chlorine after filtration is called post-chlorination.

Post-chlorination. In post-chlorination, the chlorine may be applied where the filtered water enters the clear water well or reservoir, or where the water passes from the clear water reservoir to the distribution system. In the operation of a pressure filter, the chlorine may be added to the water in the discharge line.

Post-chlorination affords a factor of safety in that it insures the potability of the water as it enters the distribution system to be delivered to the consumers. The application of chlorine after filtration affords protection against recontamination of the water in the clear water well, in reservoirs, and to some extent in the distribution system.

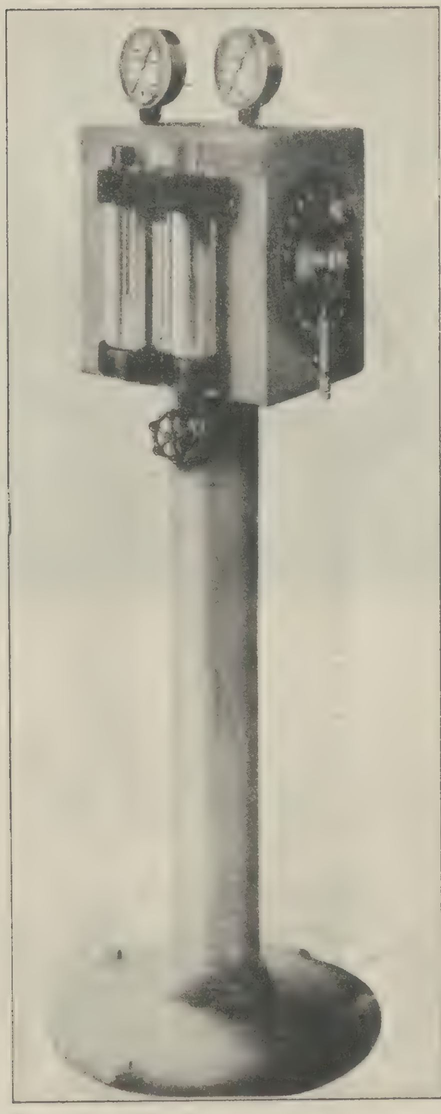


FIG. No. 69. Manual control chlorinator, solution feed type. Maximum capacity, ten pounds of chlorine per twenty-four hours. (Courtesy of the Wallace and Tiernan Co., Inc., Newark, New Jersey).

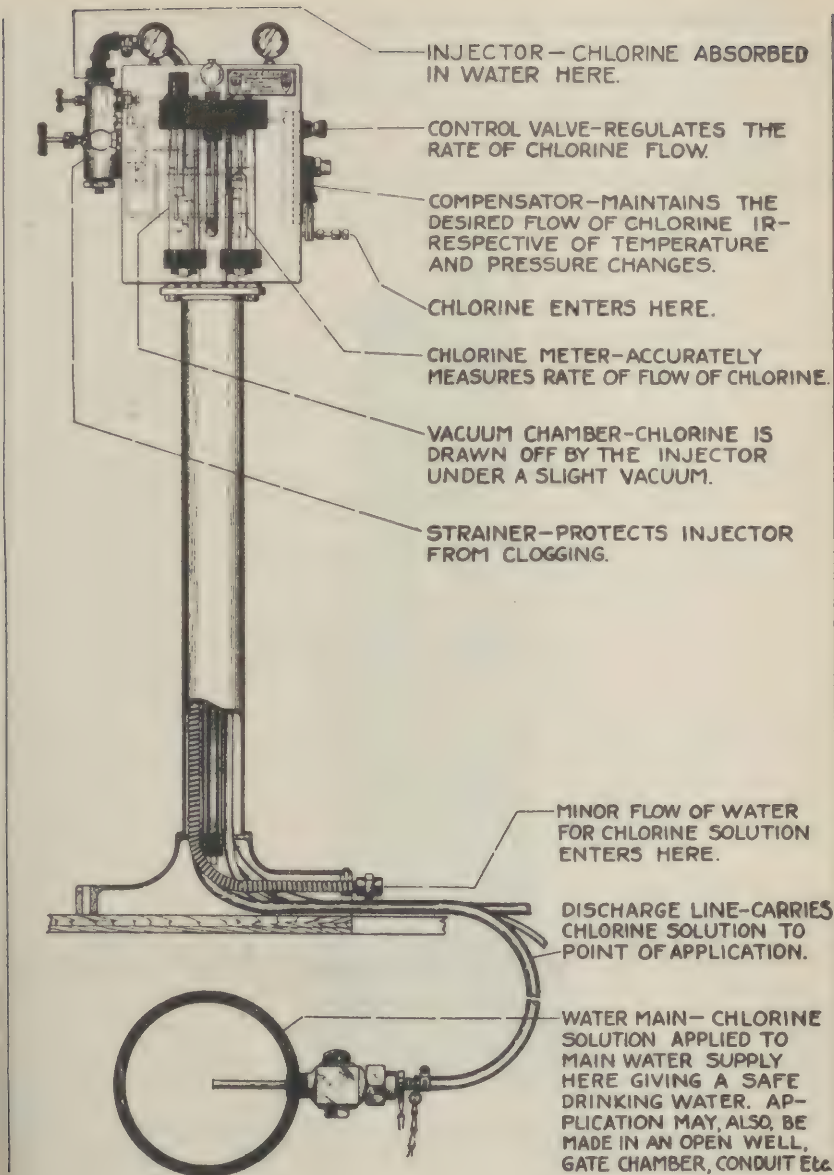


FIG. No. 70. Manual control chlorinator, solution feed type. Showing various parts of the apparatus. (Courtesy of the Wallace and Tiernan Co., Inc., Newark, New Jersey).

Pre-chlorination. Chlorine may be applied to the raw water prior to filtration, either before, during or after coagulation. This process is known as pre-chlorination and it provides an added safeguard in the elimination of pathogenic organisms. Pre-chlorination is frequently employed in conjunction with pre-ammoniation (*infra*). In some waters, pre-

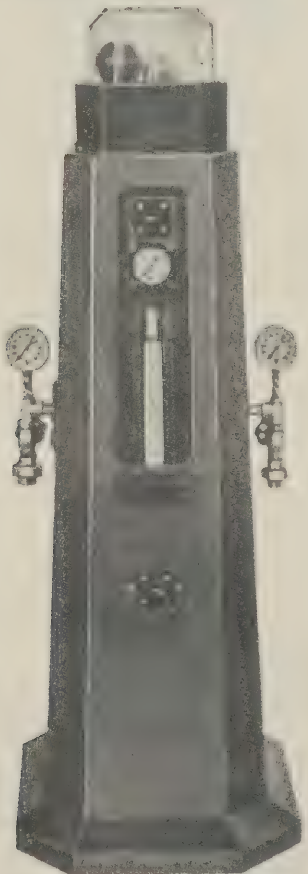


FIG. No. 71. Visible vacuum control chlorinator for feeding chlorine in solution. (Courtesy of the Wallace and Tiernan Co., Inc., Newark, New Jersey).

chlorination may be utilized to an advantage to reduce the bacterial load on the filters in the purification of heavily contaminated water. Under these conditions, pre-chlorination will increase the length of the filter runs between washings

and tends to prevent the formation of mud balls, cracks or breaks in the filter sand. Pre-chlorination will also, as a rule, reduce the quantity of chlorine which must be added to the water after filtration to provide the necessary quantity of residual chlorine.

Chlorine is an algicide and pre-chlorination may be practiced as a means of eradicating algae from sedimentation and coagulation basins and from reservoirs. Pre-chlorination will also prevent or retard decomposition of the sludge in the settling basins.

In pre-chlorination the amount of chlorine added to the water varies somewhat with the conditions present. Because of the longer contact period and the presence of more organic matter, larger quantities of chlorine can be applied in pre-chlorination than in post-chlorination without causing a chlorinous taste. Under ordinary conditions the average amount of chlorine added is usually about 1.0 p.p.m., but larger or smaller quantities may be required to give satisfactory results. In practice, chlorine is usually applied in quantities which will give a residual content of from a trace to 0.5 p.p.m. in the water on the filters.

Pre-chlorination without post-chlorination has the disadvantage that it does not provide a definite, measurable factor of safety in the form of residual chlorine in the filtered effluent, unless a sufficient quantity is applied so that some will pass through the filter. Double chlorination is frequently employed to overcome this difficulty.

The application of chlorine to the water prior to filtration may cause the development of objectionable tastes in the presence of phenol or other trade wastes. In the purification of many waters such tastes can be prevented by ammoniation or eliminated by other procedures (*infra*).

In double chlorination, pre-chlorination is employed solely for a specific purpose and the residual chlorine content in the filtered water is maintained by post-chlorination.

Ammonia-chlorine treatment. The ammonia-chlorine treatment constitutes a distinct advance in the disinfection of water supplies. When ammonia and chlorine are added to water chloramines are formed. In most waters the resulting compounds are monochloramine and dichloramine, and it is probable that some ammonium hypochlorite is also formed.

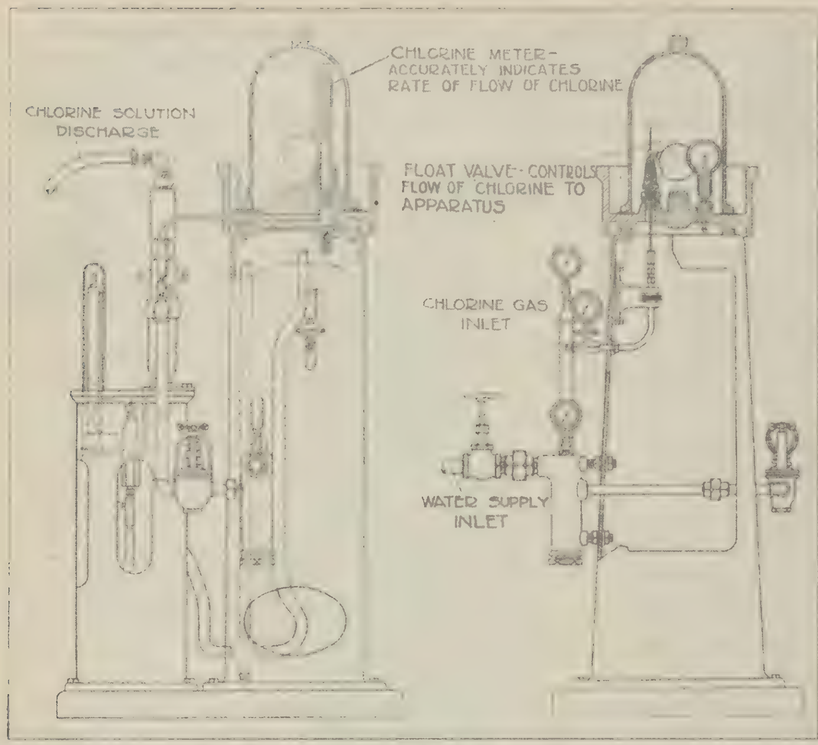


FIG. No. 72. Automatic vacuum solution feed chlorinator showing the various parts of the apparatus. (Courtesy of the Wallace and Tiernan Co., Inc., Newark, New Jersey).

As compared with chlorine alone, the disinfecting action of chloramines is delayed and prolonged. The bactericidal rate is decreased but residual chlorine, in the form of chloramines and free chlorine, is maintained for a much longer period. The velocity of disinfection is the greatest in water having a pH value of about 7.0, and decreases as the pH value increases above the neutral point. In alkaline waters having a pH of 8.5 the velocity of disinfection is much delayed. The temperature of the water also influences the bactericidal action of chloramines, the velocity of disinfection decreasing as the temperature decreases.

Residual chloramines persist for a much longer time than does chlorine alone. The continued presence of a residual disinfectant for a relatively long period of time serves to control aftergrowths in the pipes and reservoirs of the distributing

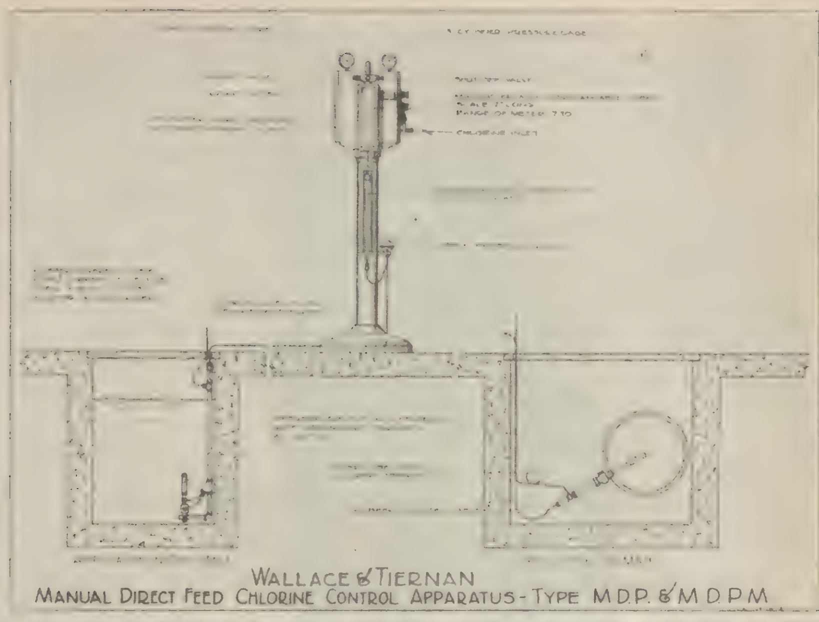


FIG. No. 73. Diagram showing method of applying dry chlorine by direct feed in open well (left) and in main (right). (Courtesy of the Wallace and Tiernan Co., Inc., Newark, New Jersey).

system, to prevent recontamination of the water, and to provide continuous disinfection of stagnant water in reservoirs and in dead ends of pipes. Where the ammonia-chlorine process is used prior to filtration, the persistence of the residual chlorine, and the larger quantity of chlorine which can be applied renders it more effective than chlorine alone in promoting the efficiency of the filters.

Ammonia-chlorine treatment permits the residual chlorine content to be materially increased without the development of chlorinous tastes. The residual chlorine is in the form of chloramines and relatively very small amounts of free chlorine. The chloramines are tasteless in the quantities present, and the small amount of free chlorine cannot be detected by taste. The residual chlorine shown to be present by the orthotolidine or the starch iodide tests includes chlorine in the form of chloramine as well as the free chlorine.

The ammonia-chlorine treatment when properly applied (*infra*) prevents the development of tastes and odors due to chlorophenol substances and reduces the tastes and odors caused

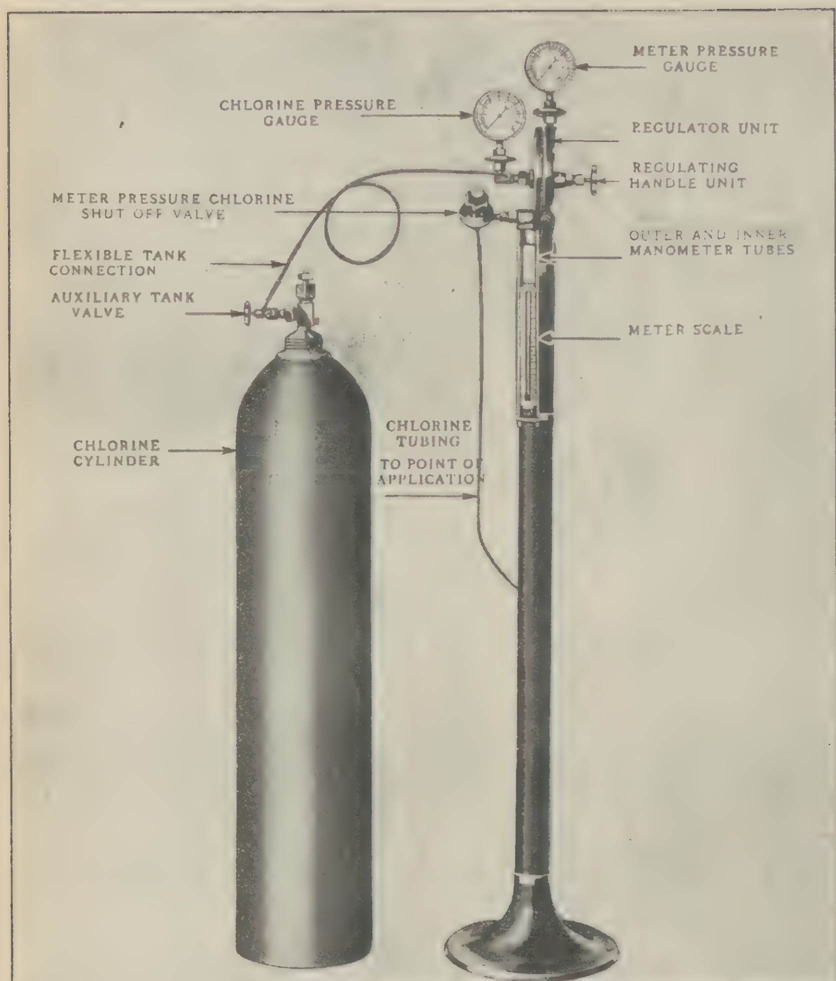


FIG. No. 74. Dry feed chlorinator. Chlorine tubing carries the chlorine from the chlorinator to a diffuser at the point of application. (Courtesy of the Paradon Manufacturing Co., Arlington, New Jersey).

by chloro-substitution compounds. The chloramines do not combine with the organic substances to form chloro-compounds while the amount of free chlorine present is too small to produce chlorophenol substitution compounds in quantities sufficient to cause tastes and odors.

FIG. No. 75. Ammoniator of the direct feed type equipped with orifice meter. Used in the application of ammonia in the disinfection of water by the ammonia-chlorine process. (Courtesy of the Wallace and Tiernan Co., Inc., Newark, New Jersey).

The ammonia is usually applied as anhydrous ammonia gas, but aqua ammonia, or ammonium sulphate, may be used. Ammonia gas is supplied in steel cylindrical tanks and is added to the water by means of apparatus similar to the chlorinators used for applying liquid chlorine (Fig. No. 75). If such apparatus is not available, the gas may be discharged from the cylinders into water in solution tanks. Weighed quantities of the gas are used and the resulting solution is applied in the same manner as the alum or calcium hypochlorite solutions (page 295). A strong solution of aqua ammonia, or of ammonium sulphate, of known strength may be used and applied at a predetermined rate by means of an orifice box or a solution feeder.

The point where the ammonia is applied depends upon the objective sought by ammoniation, and the lay-out of the plant. If the ammonia-chlorine process is employed to prevent the formation of tastes and odors caused by phenol compounds in the raw water, the ammonia should be applied prior to the addition of the chlorine. The chlorine will then combine with the ammonia to form chloramines rather than with the taste and odor producing substances with the consequent formation of chlorophenol compounds having objectionable tastes or odors. Where the ammonia-chlorine process is utilized as a pre-filtration procedure as a means of promoting the efficiency of the plant, the ammonia and the chlorine are usually applied in the mixing basin. Where ammonia is used to maintain a relatively high residual chlorine content throughout the distribution system, the ammonia may be added after filtration. In this case the ammonia may be applied at the same point and at the same time as the chlorine or prior or subsequent to the application of the chlorine. Or the water may be chlorinated before filtration and the ammonia added after filtration.

As a general rule, the ratio of ammonia to chlorine averages about one to three, that is, one pound of ammonia to three pounds of chlorine. However, the relative quantities of ammonia and chlorine vary considerably. Larger quantities of ammonia are employed where the ammonia-chlorine process is used to prevent tastes and odors. Where disinfection only is the objective sought, the ratio is adjusted to provide the maximum persistence of residual chlorine.

A longer period of contact is required for disinfection by chloramines than by free chlorine, especially if the pH value

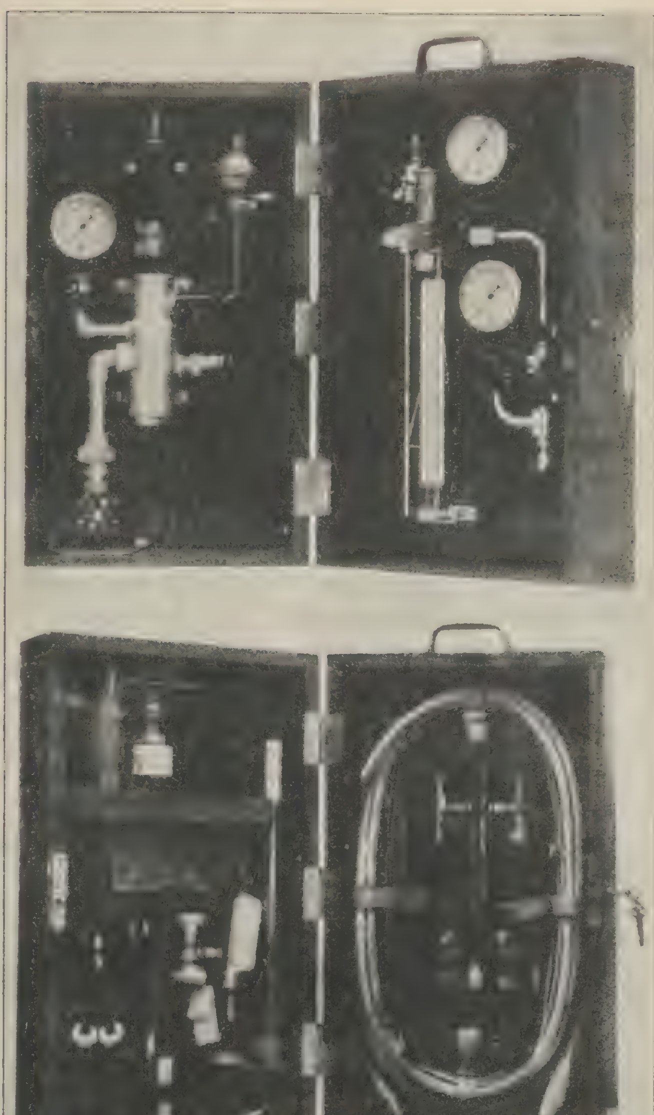


FIG. No. 76. Portable chlorinator. Upper cabinet contains chlorinating apparatus. Lower cabinet contains accessories and equipment for testing. (Courtesy of the Wallace and Tiernan Co., Inc., Newark, New Jersey).

of the water is above 7.5. A contact period of as much as two hours is necessary to obtain adequate disinfection of waters having very high pH values. However, after a two hour contact period the bactericidal action of chloramines is much more effective than when the same quantity of chlorine is used alone. The contact period required may be shortened by increasing the ratio of chlorine to ammonia, but if the relative amount of chlorine is too great tastes and odors will not be prevented.

Where the water has a pH value of above 7.0, or the temperature of the water is below 10°C. (50°F.) the presence of residual chlorine in the form of chloramines, as shown by the ortho-tolidine test, is not as reliable an index of disinfection as residual chlorine in the form of free chlorine. Consequently, where these conditions obtain, frequent bacteriological analyses of the water should be made to determine if disinfection is being effected.

Efficiency of chlorine as a disinfectant of water. Theoretically, all the typhoid-dysentery-colon group of bacteria in a water supply can be destroyed by chlorine. Practically, the application of sufficient chlorine to disinfect unfiltered water containing large amounts of organic matter will render such water non-potable by causing the development of obnoxious tastes. Generally, if the water contains organic matter in such quantity that more than 2 parts per million of chlorine must be applied to produce residual chlorine of from 0.2 to 0.5 parts per million, the compounds formed by the union of the chlorine with the organic matter will render the water non-potable.

While residual chlorine in quantities of from 0.2 to 0.5 parts per million will destroy all the pathogenic bacteria capable of producing intestinal disease, the cysts of *Endameba histolytica* are apparently more resistant (page 176). Until this subject has been more thoroughly studied, filtration through sand is the most reliable method of removing the cysts of *Endameba histolytica* from a water supply.

Disagreeable tastes. The disagreeable tastes which sometimes occur in chlorinated water are due to an excess of free chlorine or to a combination of the chlorine with organic compounds in the water to form chloro-substitution products. Industrial wastes containing phenol or benzol compounds are a frequent cause of tastes in chlorinated water. Certain vege-

table matter when acted upon by a comparatively small amount of chlorine will produce disagreeable tastes. The average person will notice a chlorinous taste in the water when about 0.4 to 0.5 parts per million of residual chlorine are present. Less than 0.4 parts per million of free chlorine does not by itself produce an objectionable taste. The taste produced by small amounts of free chlorine alone will not usually be so obnoxious as to render the water non-potable. The prevention or eradication of tastes and odors in water is discussed on page 317.

The orthotolidine test for residual chlorine. The orthotolidine reagent used for determining the presence of residual chlorine in water is prepared by dissolving one gram of orthotolidine crystals in 100 c.c. of dilute hydrochloric acid. The dilute hydrochloric acid is made by diluting 100 c.c. of the concentrated acid with 900 c.c. of distilled water. Proportional amounts of the ingredients are used in making smaller quantities of the reagent. When a small quantity of the colorless orthotolidine solution is added to water containing residual chlorine, a light yellow to orange red color is produced, the intensity of the color depending, within limits, on the amount of chlorine present.

The test is made by adding one c.c. of the orthotolidine reagent to 100 c.c. of the water to be tested. In the operation of water purification plants, and in the field where conditions permit, the water should be tested at a temperature of 20°C., and after the addition of the orthotolidine reagent the sample should be placed in the dark while the color develops. In any event, the sample being tested should never be exposed to direct sunlight. The time allowed for the color to develop to the maximum degree should be from five minutes to not more than fifteen minutes, but the reading should be made when the maximum color is present. As a rough quantitative measure for use in field work, it may be considered that 0.5 part per million of residual chlorine will produce a light canary yellow; one part per million a deep yellow, and that an orange red color indicates over-chlorination.

Small quantities of residual chlorine can be accurately estimated by comparing the color developed in the tested sample of water with permanent color standards. The solutions used for permanent color standards are prepared as follows:

Copper sulphate solution. Dissolve 1.5 grams of copper sulphate and 1 c.c. of concentrated sulphuric acid in distilled water and make up to 100 c.c.

Potassium dichromate solution. Dissolve 0.025 grams of potassium dichromate and 0.1 c.c. of concentrated sulphuric acid in distilled water and make up to 100 c.c.

The standards are prepared by mixing these solutions in the proportions shown in the following table and diluting to 100 c.c. with distilled water.

Chlorine	Solution of copper sulphate	Solution of potassium dichromate
Parts per million	*c. c.*	*c. c.*
0.05	0.4	5.5
.1	1.8	10
.2	1.9	20
.3	1.9	30
.4	2.0	38
.5	2.0	45

The standard solutions are usually placed in 100 c.c. or 50 c.c. Nessler tubes. Four ounce, clear glass bottles may be used instead of tubes. If fifty c.c. tubes are used in making the test, from seven to eight drops of the orthotolidine should be used instead of one c.c. (*supra*).

The color of the water being tested should be compared with

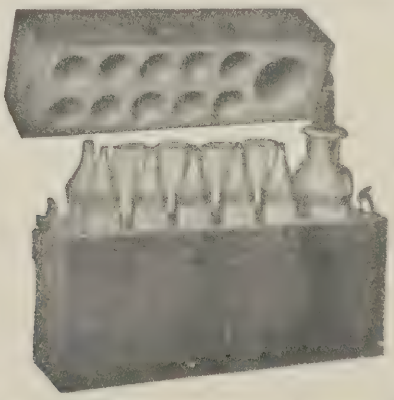


FIG. No. 77. Enslow chlorine comparator, LaMotte. This set is used for measuring the residual chlorine in water supplies, swimming pool water or sewage by the orthotolidine test. The sealed glass ampules contain color standards representing 0.05, 0.10, 0.2, 0.5, 0.8, and 1.0 parts per million of chlorine. (Courtesy of the Central Scientific Company, Chicago, Ill.).

the color of the standards by looking directly downward through the unstoppered tubes, preferably towards a white background. Various kinds of comparators for measuring the color produced by the orthotolidine reaction have been devised (Figures No. 77 and 78).

In the operation of the average water purification plant a convenient, and a sufficiently accurate method of testing for residual chlorine consists of using two standard tubes, one representing 0.1 part per million and the other 0.3 parts per million of free chlorine. The color developed in the tested water should be deeper than the color of the standard representing 0.1 part per million and lighter than that representing 0.3 parts per million.

The development of a false color may occasionally cause difficulty in using the orthotolidine test. The color developed by the orthotolidine reagent in the presence of chlorine is due to oxidation, and, consequently, other oxidizing agents may produce a similar color or modify that due to the chlorine. These false colors usually develop in the presence of more than 0.01 p.p.m. of manganic manganese, 0.3 p.p.m. of iron, or 0.3 p.p.m. of nitrites. Nitrites in quantities of less than 0.3 p.p.m. will not cause false color if the contact period allowed for color development is less than 15 minutes. Frequently, a blue or bluish green color is produced when orthotolidine is added to alkaline waters containing residual chlorine. The procedures for testing for residual chlorine in the presence of substances which cause false color are described in Standard Methods of Water Analysis, 8th Edition, American Public Health Association.

The Enslow test provides a simple method of determining roughly the degree of interference caused by false color due to manganese. A sample of the water is tested with orthotolidine in the usual manner and the resulting color is assumed to be that produced by the chlorine and the manganese together. Another sample of the water is boiled for fifteen minutes and then tested with orthotolidine. The chlorine present in the second sample is dissipated by the boiling and the color formed by the addition of orthotolidine thereafter is due to manganese alone. If the color reading of the second sample is subtracted from that of the first sample

FIG. No. 78. Hellige pocket color comparator for determining color values of water. Used in determining chlorine content of water by the orthotolidine test. (Courtesy of Eimer and Amend, New York, N. Y.).

the difference is a rough measurement of the quantity of residual chlorine in the water being tested.

The starch iodide test. If the reagents for the orthotolidine test cannot be obtained, the starch iodide test may be used to determine the presence of free chlorine in the water. The reagents required are a stock starch solution and crystals of potassium iodide. The starch solution is made by first mixing one gram, or one-fourth teaspoonful, of starch with a small amount of water to form a thin paste. The paste is added to about 200 c.c., or one cupful, of boiling water and boiled for a few minutes. The cooled paste solution should be filtered if necessary to remove undissolved particles. A few drops of chloroform may be added as a preservative.

The test is performed by adding, in the order named, two or three crystals of potassium iodide and ten to twenty drops of the starch solution to about 100 c.c., or three to four ounces, of the water to be tested. The sample should be thoroughly shaken after the reagents are added. If a blue color develops the sample contains free chlorine.

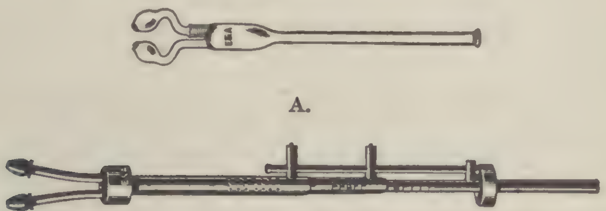
The starch iodide test is not a quantitative test. If a light blue color develops, it may be assumed that the water contains about the proper quantity of chlorine. If the color

is dark blue, it is probable that too much chlorine is present. As the intensity of the color may increase on standing, only that which develops within five minutes after the reagents are added should be considered. If the water is turbid or colored, a control test may be made by adding the starch solution alone without the potassium iodide to a sample of the water.

In testing water which has been treated with ammonia and chlorine the starch iodide test, like the orthotolidine test, demonstrates the presence of residual chlorine in the form of chloramines and as free chlorine.

TASTES AND ODORS

Most of the objectionable tastes in water are in reality odors and are detected by the sense of smell rather than by taste. Procedures for measuring the concentration of an odor and methods of expressing the results are described in Standard Methods of Water Analysis, 8th Edition, 1936, published by the American Public Health Association. Modified procedures and technique are given by Baylis in his book *Elimination of Tastes and Odors in Water*. The quality of the odor is determined by the sense of smell of the observer and the intensity by dilution of the odor-bearing water with odor-free water or by dilution of the air over the water in a flask. Types of osmoscopes used to draw the air from the flask to the nostrils are shown in Fig. No. 79.



A.

B.

FIG. No. 79. A—Osmoscope, Type A Fair-Wells. B—Osmoscope, Type B Fair-Wells. These instruments are used to measure intensity of odors in water. (Courtesy of Eimer and Amend, New York, N. Y.).

The disagreeable tastes and odors which develop in water, especially in chlorinated water, may be due to any one of a number of causes. One of the most common causes is trade wastes containing phenol or benzol compounds. Tastes and

odors are also due to excess chlorine alone; to organisms such as diatoms, algae or protozoa; to the decomposition of organic matter such as leaves, brush or logs, in the deeper levels of impounding reservoirs; to the decomposition of sludge in coagulation basins, and to the action of chlorine on pipe coatings or sediment.

The trade wastes responsible for tastes and odors in water are generally those derived from such industries as coke ovens, gas works, or oil refineries. The substances causing tastes and odors are for the most part phenol compounds, and are, as a rule, tasteless in themselves in the dilutions obtained in the ordinary water supply. However, marked tastes and odors develop on contact with *free* chlorine, due to the formation of chlorophenol compounds. These tastes are usually described as medicinal in character or as resembling iodoform or carbolic acid.

The elimination of a taste or odor due to industrial wastes is best accomplished by preventing the waste in question from entering the water supply. If the source of the waste can be determined, the owner of the industry can usually be required under local laws to institute suitable control measures to protect the water supply. Where the water cannot be protected from industrial wastes, several methods are available by which the tastes and odors can be eliminated by treatment of the water. The principal procedures employed for this purpose are treatment with ammonia, treatment with activated carbon, superchlorination, and aeration.

Ammonia-chlorine treatment. The ammonia-chlorine process is described on page 305.

Activated carbon. Treatment with activated carbon is becoming the method of choice in eliminating tastes and odors from water. Activated carbon is produced by carbonizing suitable substances at low temperatures in closed vessels and subsequently "activating" the carbon by treatment with air or steam. The types of activated carbon most commonly used in the treatment of water supplies are *hydrodarco* and *aqua nuchar.* The former is made from lignite and the latter from certain waste products of paper mills.

Activated carbon has high adsorptive capacity not possessed by ordinary charcoal and eliminates tastes by adsorption of taste producing compounds and substances. Practically all

compounds which produce tastes in water are adsorbed by activated carbon.

In most instances activated carbon is applied in powdered form. More rarely, the water may be passed through beds of granular carbon. The fineness of the powdered carbon should be such that it will pass through a screen having a mesh of 200 to the inch.

The powdered activated carbon is added to the water in the mixing basins, in the coagulation or settling basins, or on the filters. Ordinarily, it is applied in the mixing basins, either with or subsequent to the addition of the coagulant. The carbon may be mixed with the alum (black alum or activated alum). In the treatment of very turbid waters, the carbon may be added to the water in the settling basins, or to the water on the filter.

Powdered activated carbon may be used to stabilize the sludge in the settling basins and thus eliminate tastes and odors caused by the decomposition of the sludge. Carbon added to the water in the mixing channel will be mixed with the sludge over the entire bottom of a relatively small settling basin. Where the settling basins are larger the carbon will not reach the sludge near the outlet and an additional amount must be applied at some point in the settling basin.

Where superchlorination is practiced, treatment with activated carbon may be employed to dechlorinate the water. The carbon is added to the water, subsequent to the chlorine, either in the settling basins or on the filter. Chlorine and chlorine compounds are most effectively adsorbed by carbon on or in the filters.

Powdered activated carbon may be applied by means of dry-feed machines (page 272). Solution tanks may be used (page 267), but the water must be thoroughly agitated at all times in order to keep the carbon in suspension. Whatever method of application is employed, the particles of carbon must be thoroughly wetted to prevent them from floating on the water.

Ordinarily, activated carbon is applied in quantities ranging from 0.5 p.p.m. to 10 p.p.m. The amount actually required for the treatment of a given water supply depends on the existing conditions and varies with the character of the water. Usually, the rate of application is determined by experimentation.

Superchlorination. The development of tastes due to certain of the phenolic compounds may be avoided by the ap-

plication of chlorine in quantities ranging from 1.0 to 3.0 parts per million. Large doses of chlorine apparently destroy some of the phenol compounds where smaller doses form chlorophenols. Prior to dechlorination the chlorine should be allowed to act for a period of time sufficient to destroy the phenolic compounds. Usually, a contact period of from one to two hours is required. The tastes caused by some of the phenolic compounds cannot be removed by superchlorination. The taste may be disguised by the excess chlorine but reappears when the water is dechlorinated.

In the chlorination of turbid waters or where it is desired to maintain a high residual chlorine content to protect against recontamination, excess chlorine may be required in quantities which will cause obnoxious tastes due to chloro-compounds. Also, relatively large quantities of chlorine may be employed for the purpose of preventing tastes due to algae or protozoa (page 322).

Where it is necessary to use chlorine in such quantities as to produce a disagreeable taste, the excess chlorine, and, to a certain extent, some of the chloro-compounds can be eliminated by the application of activated carbon. An "antichlor" such as sulphur dioxide or sodium thiosulphate can be used to neutralize the excess chlorine.

Sulphur dioxide is usually applied as a gas by means of apparatus similar to that employed for the application of liquid chlorine. Sodium thiosulphate is applied as a solution in the same manner as calcium hypochlorite. The quantity of a dechlorinating agent required depends largely on the quantity of excess chlorine to be neutralized and should be determined by suitable tests. The amount of sulphur dioxide required usually varies from 0.5 to 2.0 parts per million. Sodium thiosulphate is usually applied in quantities equal to about twice the amount of excess chlorine present.

Superchlorination with subsequent complete dechlorination has the major disadvantage that no residual chlorine remains in the water. Partial dechlorination or rechlorination may be used to obtain the proper quantity of residual chlorine. In any event superchlorination as a purification process requires skilful supervision to insure proper disinfection.

Excess chlorine can, in some instances, be removed by aeration. The water may be sprayed through nozzles, dis-

charged in thin sheets over weirs, or stored in open reservoirs. The amount of spraying required or the length of the storage period must be determined by tests and experimental work.

Algae, diatoms, etc. Algae and diatoms are plant forms which require sunshine, carbonic acid, nitrogen and minerals for their growth and development. Consequently, they grow and are to be found at or near the surface of open water. Algae develop best in quiet waters and are seldom found where the water is disturbed by currents or waves. As they also require sunshine, algae grow most plentifully in such places as large impounding reservoirs, lakes or ponds, particularly in the shallow areas and in the indentations along the edges of streams.

There are many different kinds of algae. Some produce a marked color in the water, and of these the species which cause a greenish scum on the water are examples. Many have a distinctive odor. An aromatic or geranium odor is produced by diatomaceae and a few protozoa; a fish-like odor is caused by certain chlorophyceae, diatomaceae and protozoa, while a grassy odor results from the growth of cyanophyceae (blue-green algae). The cyanophyceae usually become prevalent in the summer and autumn, the diatoms grow most luxuriantly in the spring and autumn, while certain of the protozoa which produce tastes and odors develop in the winter and will grow under ice.

Frequently, the tastes and odors caused by the growth products of micro-organisms can be removed from water by aeration. Usually, this is done either by spraying the water into the air or permitting it to fall through the air.

The development of algae in artificial reservoirs and basins can be prevented by covering the reservoir and thus depriving the organisms of the sunshine necessary for their growth.

Most of the algae and protozoa commonly found in water can be destroyed by treating the water with from 0.1 to 0.5 part per million of copper sulphate (12 ounces to 4 pounds per million gallons of water). The method selected for applying the copper sulphate should be one which will give the best distribution under local conditions, and care must be taken to avoid over treatment or under treatment of a part of the water. The desired quantity of copper sulphate may be

placed in a cloth bag and pulled through the water. In the case of lakes, ponds or large reservoirs, the sack containing the copper sulphate may be dragged behind a boat until the chemical is dissolved and distributed in the water. The copper sulphate can also be applied as a powder by means of a blower mounted in a boat. Under suitable conditions copper sulphate may be applied in a dry form or as a solution by the methods described for the application of alum or calcium hypochlorite (page 295).

The use of copper sulphate is sometimes followed by a marked increase in tastes and odors in the water due to the release of oils from and the decomposition of the dead organisms. As a rule, these tastes and odors disappear in a comparatively short time, or they can be removed by aeration.

Chlorine is an effective agent for the destruction of the algae commonly found in reservoirs. It will not only kill these algae but the excess chlorine not required for algicidal purposes will, in many instances, also remove the tastes and odors due to the oils released by the dead organisms. The dosage of chlorine required to kill algae, and eradicate the disagreeable tastes and odors, varies from 0.3 to 1.0 p.p.m., or sufficient to produce a residual chlorine content of from 0.05 to 0.2 p.p.m. Superchlorination with relatively large doses of chlorine followed by rechlorination is effective in some instances. Small doses may destroy the organisms without removing the tastes and odors.

Chlorine is a more desirable algicide in some instances than copper sulphate. Where it can be added to the water as it flows into a reservoir, chlorine is easier to apply than copper sulphate and the application can be more accurately controlled. It is also less expensive than copper sulphate.

Turnover of reservoir or lake water. When a reservoir or lake is more than twenty feet in depth, stratification of the water due to difference in temperature tends to occur. During the summer, the surface of the water is warmer than at deeper levels. In the autumn, when the temperature of the surface decreases to 4°C. (39.2°F.), which is the point of maximum density of water, the upper layer gradually sinks to the bottom and the warmer and lighter bottom layer rises to the surface. In cold climates, a spring turnover also occurs when the temperature of the surface layer rises to 4°C.

(39.2° F.) causing it to sink to the bottom and force the colder and lighter bottom layer to the surface. The movement of the water due to a turnover may subside in a few days or may continue for several weeks. Organic matter undergoes decomposition in the deeper layers of the water and the products of this decomposition are brought to the surface by vertical currents resulting from the turnover of the water, imparting to the water a disagreeable taste.

The production of tastes by the turnover of the water in large reservoirs or lakes is difficult to prevent. In some instances, the intakes can be so arranged or constructed that water can be drawn from different levels so as to reduce to a minimum the quantity of affected water admitted to the system. Ordinarily, the tastes disappear within a few days after the movement of the water ceases. They can usually be eliminated by treatment with activated carbon, by ammonia-chlorine treatment, or by aeration.

WATER SOFTENING

Water softening is the process of removing from water, wholly or partially, the soluble minerals that cause hardness. There are two general types of hardness,—carbonate and noncarbonate. Carbonate, or temporary hardness, is due to the presence of soluble bicarbonates of calcium or magnesium. Noncarbonate, or permanent hardness, is usually caused by calcium or magnesium sulphates, but may be due to chlorides or nitrates of calcium or magnesium. The salts which cause hardness in water are not, in the amounts usually present, detrimental to health. They do, however, impair the value of a water for purposes other than drinking and cooking, such as for steam, heating, and laundering.

The amount of hardness is determined by laboratory analysis of the water and is expressed in terms of calcium carbonate in parts per million, or grains per gallon. One grain per gallon is equal to 17.1 parts per million.

The quantity of hardness which will render it desirable or necessary that the water be softened depends on the purposes for which the water supply is used and the nature of the salts causing the hardness. In some waters, excessive hardness may cause a disagreeable taste or interfere with cooking,

but carbonate hardness of not more than 300 parts per million, or noncarbonate hardness somewhat in excess of this amount will not render the water unfit for drinking and cooking.

Water containing as much as 150 parts per million total hardness should be softened before being used in heating plants, for steam, or in laundry work. Such water will form large amounts of scale in tubes, pipes, and boilers and has a high soap consuming power.

It is not practicable or necessary to remove all the hardness by softening. Ordinarily, a reduction to less than 50 parts per million of noncarbonate hardness and 100 parts per million of total hardness is sufficient.

As a general rule water softening results in an economic saving. The money losses due to the excessive consumption of soap, damage to hot water systems, and injurious effect on fabrics, are greater than the cost of softening the water. In the operation of all but the smaller plants, the saving from soap alone will usually meet the cost of softening the water.

Methods of softening. Two general methods are used to soften water; first, by treatment with lime or soda ash; and second, by passage of the water through zeolite. The carbonate hardness, that is, the hardness due to the bicarbonates of calcium or magnesium, can also be removed by heat which converts the soluble bicarbonates into insoluble carbonates and carbon dioxide. The carbonates can then be settled out of the water.

Lime and soda ash. Lime is used to remove carbonate hardness. When water containing calcium or magnesium bicarbonates is treated with lime, the calcium hydroxide combines with the soluble bicarbonates to form insoluble carbonates. Magnesium hydroxide may be formed as a flocculent precipitate. Quicklime may be used for this purpose but, ordinarily, hydrated lime is employed. The lime suspension is mixed in iron or steel tanks and applied in the same manner as other chemicals (page 267).

The addition of soda ash (sodium carbonate) to water containing calcium or magnesium sulphates (noncarbonate hardness) results in the formation of insoluble calcium carbonate and magnesium hydrate, and soluble sodium sulphate. The sodium sulphate is harmless in the amount present and

does not cause hardness. The soda ash is applied as described on page 267.

The insoluble compounds resulting from treatment with lime or soda ash are removed from the water by sedimentation or filtration, or both. Where the water softening process is followed by rapid sand filtration, the addition of the chemicals and the subsequent sedimentation is a part of the pre-filtration treatment.

Theoretically, 100 parts per million of carbonate hardness will be removed by 3.2 grains of calcium oxide (lime) per gallon, and 100 parts per million of noncarbonate hardness by 6.3 grains of sodium carbonate (soda ash) per gallon. However, zero hardness cannot be produced by this method and a certain amount of residual hardness will remain after treatment. The quantity of residual hardness depends somewhat on the hardness of the raw water and other factors, and varies from 35 parts per million to 75 to 100 parts per million.

Excess lime and re-carbonation. In the treatment of many waters the lime-soda ash method of softening has certain disadvantages. Where the water is filtered, the sand grains become incrusted and cemented together with deposits of calcium carbonate. Deposits form in pipes and meters. Frequently, the total hardness cannot be reduced to the desired degree, because the magnesium is not precipitated. Treatment with excess lime followed by re-carbonation with carbon dioxide will, in most instances, reduce the carbonate hardness to 20 to 25 p.p.m., and so stabilize the water as to eliminate deposition of carbonates. The theoretical solubility limit of calcium carbonate is 18 to 20 p.p.m., but this limit is seldom reached in actual practice.

The methods employed in softening water with excess lime vary considerably according to the character of the water and the layout of the plant. Usually, an excess of lime is added to the water sufficient to produce from 25 to 50 p.p.m. of caustic alkalinity. Carbon dioxide is then added to the water to convert the caustic alkalinity into carbonate alkalinity and to stabilize the water. All, or nearly all, the magnesium is precipitated by this method. The floc produced by the lime-soda ash treatment is settled out in settling basins constructed for that purpose, or in the ordinary coagulation basins (page 247).

The carbon dioxide is usually derived from coke, gas or oil. The gas is passed through scrubbers and condensers and applied to the water in carbonation chambers in amounts sufficient to produce the desired reactions.

FIG. No. 80. Apparatus for generating and applying carbon dioxide in the re-carbonation of water. Gas is generated by burning coke, gas or oil. The gas is scrubbed and compressed before being applied to the water. (Courtesy of the International Filter Co., Chicago, Ill.).

This basic method of softening may be, and usually is, subject to one or more modifications. It may be necessary to apply the carbon dioxide at two different points in order to effect the desired stabilization. The sludge in the settling basins may be mechanically removed with clarifiers (page 623) and a part of it returned and mixed with water to be settled. A process of split treatment is sometimes employed by which a part of the water is softened and subsequently mixed with the remaining hard water. Water which has been softened by the lime-soda ash process and re-carbonated may be further softened by passing all or a part of the supply through zeolite softeners (Fig. No. 81).

Zeolite. Zeolites are hydrous double silicates of aluminum and another metal, usually sodium. They occur as natural minerals or are made synthetically. Physically, zeolite is sand through which water can be filtered for softening purposes. Some of the natural zeolite sands have an effective size of about 0.4 mm. and a uniformity coefficient of 1.6 (page 254). The synthetic zeolite is either the processed glauconite known as greensand, or precipitated gel.

When hard water is brought into contact with zeolite there is an interchange of bases. The calcium or magnesium in the water is replaced by sodium from the zeolite and the sodium in the zeolite sand is replaced by calcium or magnesium from the water. No precipitate is formed as in the lime or soda ash treatment. The sodium salts remaining in the water are soluble but do not make the water hard. All the hardness can be removed by zeolite treatment.

The zeolite becomes inert as the sodium is replaced and will no longer remove the calcium and magnesium salts from the water. When this occurs the zeolite is regenerated by washing with a saturated solution of sodium chloride. The method of washing is, in principle, the same as that used in washing a pressure filter (page 288). During the washing process the calcium and magnesium in the zeolite are replaced by sodium from the sodium chloride. The excess sodium chloride is then removed from the softener by washing with water. The quantity of sodium chloride solution and the time required for regenerating a softener unit is determined by tests and experience. Usually, in the case of a comparatively large unit, using synthetic zeolite, from 30 minutes to an hour is

required to complete the regeneration process and put the unit back into service. Ordinarily, common rock salt is used for making the sodium chloride solution (Fig. No. 81).

FIG. No. 81. Zeolite softener installation. The two tanks on the right contain the zeolite through which water passes under pressure. The tank on the left contains the brine for regeneration of the zeolite. (Courtesy of the American Water Softener Co., Philadelphia, Pa.).

If a softening plant is properly designed and operated the loss of zeolite should be not more than three or four per cent a year.

The ordinary zeolite softening unit is essentially a pressure filter (page 288), in which the filter material consists of zeolite. The filter unit is usually a vertical steel cylinder containing a bed of zeolite from 20 to 40 inches in thickness through which the water to be treated is passed either upward or downward. The sodium chloride solution used to regenerate the zeolite is supplied to the filter from a solution tank.

Frequently, it is not necessary or desirable to soften a water supply to zero hardness. The amount of hardness desired can be obtained by softening a part of the water by the zeolite process and by-passing the remainder. The two portions are then mixed together. Where the water contains iron, it may be undesirable to by-pass an unsoftened portion (*infra*).

The zeolite softener does not remove turbidity from water. Turbid water should be softened by treatment with lime or soda ash, or filtered before being subjected to the zeolite process of softening. Sodium salts or free acids will interfere with the action of the zeolite. Zeolite softeners will not remove insoluble iron compounds from the water, and iron

in an insoluble form will eventually clog the sand. Where iron bearing water passes directly from a well to a zeolite softener without being exposed to the air, the iron does not interfere with the softening action of the zeolite.

Ordinary zeolite will remove soluble iron and manganese from water. Also, zeolites are manufactured especially for the removal of iron and manganese. The oxides of manganese on the surface of the granules oxidize and remove the iron and manganese as the water passes through a bed of the zeolite. The zeolite is regenerated with potassium permanganate.

One cubic foot of zeolite will remove about 3000 grains of hardness. The number and size of the units required for any given plant depend on the capacity of the plant, and the amount of hardness which is to be removed. In any event, there should be two or more units in order to provide for placing one or more units out of service for regeneration.

The zeolite will remove chlorine from the water. If chlorine is added to the water prior to passage through a zeolite softener, provision should be made for a contact period of at least ten minutes.

Zeolite softeners are most frequently used in connection with heating or steam plants, or laundries, but may also be employed for the treatment of the entire water supply for a station or camp.

REMOVAL OF IRON AND MANGANESE

The presence of iron in water in quantities of 0.5 parts per million or more is manifested by a rusty or brownish red precipitate or stain on plumbing fixtures and on clothing or utensils washed in the water. Such water may also have a slight metallic taste. Iron bearing water promotes the growth of crenothrix, the so-called iron bacteria, in water and pipes. These organisms may be present in sufficient numbers to cause clogging of the service pipes and mains. They also tend to increase the staining properties of the water and may cause a disagreeable odor.

Manganese produces effects similar to those caused by iron and is usually associated with iron in ground waters. When occurring with iron, the quantity of manganese is usually less than that of the iron.

In clear underground water, iron or manganese, or both together, in excess of 0.3 parts per million will usually cause trouble and complaints. If the water contains considerable organic matter, as much as one part per million may be present without producing any noticeable effect.

Methods of removal. Iron and manganese are present in water as soluble compounds and the processes employed for their removal are based primarily on oxidation and subsequent precipitation of the insoluble oxides. No one method has been devised which is applicable to all waters. The presence of other chemicals or of organic matter may interfere with the removal of either iron or manganese and necessitate the adoption of special methods. Manganese is as a rule more difficult to remove than iron. The usual methods of removing iron or manganese from water include aeration, sedimentation treatment with lime and alum, and passage through contact beds or sand filters. These processes may be employed singly or in various combinations. Certain of the zeolites will remove iron and manganese from water (*supra*).

Aeration. Aeration of water containing iron or manganese may be accomplished by various methods, such as for example, spraying through aerators, by contact in contact beds, or by exposure to the air in reservoirs. Where ground water is recovered with an air lift pump, the water is usually aerated sufficiently to cause the oxidation of any iron or manganese compounds which it may contain.

Only a very small amount of dissolved oxygen is required to oxidize iron or manganese. Too large a content of dissolved oxygen may interfere with removal processes. Consequently, the degree of aeration which will be most effective in the treatment of a given water supply must be determined by experimentation.

Occasionally it may be feasible to use an oxidizing chemical, such as permanganate, hypochlorite, or chlorine. Usually; however, oxidation can be more satisfactorily accomplished by some other method.

Plain sedimentation. The removal of iron and manganese can be effected by plain sedimentation where the water is alkaline and contains but little organic matter. This method is the most successful when the water contains relatively large amounts

of iron and manganese. It is slow and uneconomical and is seldom employed where other procedures are available.

Lime and alum treatment. The application of lime subsequent to aeration will hasten the precipitation of the insoluble oxides. Coagulation with alum, or with alum and lime, followed by sedimentation will facilitate the removal of iron and manganese by subsequent contact action.

Contact. Contact beds of coarse broken material are used as oxidizing agencies. The contact material may consist of broken stone, coke, coal, slag, gravel, or pieces of wood. The water flows in a thin film over the surfaces of the contact material. A coating of oxidized minerals forms on the surfaces of the contact material and serves to oxidize the iron and manganese in the water flowing through the bed. The oxides are deposited on the contact material and the contact beds must be cleaned at intervals to prevent clogging. Usually the beds are cleaned by flushing or back washing.

Contact beds are the most effective where the water has a relatively high iron or manganese content. This method has the disadvantage, however, that, in many instances, it will not reduce the iron or manganese to less than 0.5 part per million and further treatment, such as filtration, is necessary.

Filtration. Filtration through sand will frequently be found effective in the removal of iron and manganese. Either the rapid or slow filters are employed for this purpose. As the rapid sand filtration process includes coagulation with alum and sedimentation, this method is generally more successful in the removal of iron and manganese than is slow sand filtration. Usually, it will be necessary to treat the water by aeration or contact prior to filtration.

Removal with zeolite. Iron and manganese can be removed by contact with certain kinds of synthetic zeolites (page 329).

REMOVAL OF FLUORIDE

The presence of fluoride in water used for domestic purposes is the cause of chronic endemic dental fluorosis. This condition is manifested by mottling of the enamel of the teeth and affects children who consume water containing fluoride for a relatively long period of time. The mottling of the enamel usually appears as a brownish or yellowish stain. At times the teeth are black or

an opaque white. In the more severe cases there is deep pitting of the enamel followed ultimately by destruction of the teeth.

Mottled enamel usually occurs only when the water supply contains at least 1.0 p.p.m. of fluoride. Ordinarily. fluoride is present only in ground waters and, consequently, chronic endemic dental fluorosis tends to occur only among the children of communities, or families, supplied with water from wells or springs.

The quantity of fluoride in a water supply can be reduced by several methods. The application of lime, alum or activated carbon will, in the treatment of many waters. reduce the fluoride present to less than 1.0 p.p.m. The removal of fluoride by the application of lime apparently depends upon the precipitation of magnesium, the fluoride being adsorbed by the gelatinous precipitate of magnesium hydroxide. Experimental work indicates that the precipitation of about 50 p.p.m. of magnesium is required to remove 1.0 p.p.m. of fluoride. Consequently, as waters may contain relatively large amounts of fluorides, it may be necessary to add large amounts of magnesium to the water in order to effect a reduction of the fluoride content to below 1.0 p.p.m. It may be, for this reason, economically impracticable to attempt to treat water containing a relatively large quantity of fluoride.

Fluorides can be removed from water by the application of large doses of alum. In some instances, eleven to twelve grains of alum per gallon have been required to remove one part per million of fluoride. Other workers have succeeded with smaller proportionate doses of alum.

Experimentally, the concentration of fluoride in water has been reduced by the use of activated carbon. Apparently, activated carbon is effective only when the pH is 3.0 or below.

Because of the difficulties encountered in reducing the fluoride content of water, it is usually more economical to develop another supply having a fluoride concentration of less than one p.p.m. than to effect removal of the fluoride by treatment.

PREVENTION OF CORROSION

Internal corrosion of water pipes occurs when the oxygen in the water attacks and dissolves the metal of the piping. Corrosion interferes with the flow of water through the pipes by

the formation of incrustations and roughened areas and ultimately, through disintegration of the pipe walls, results in leakage and wastage of water and destruction of the pipes. Internal corrosion of iron pipes causes red water and iron stains on plumbing fixtures.

Corrosion is an electro-chemical phenomenon and the corrosiveness of water containing dissolved oxygen is largely governed by the hydrogen ion concentration, the carbon dioxide content, the alkalinity and the mineral content. Corrosion can be prevented by the removal of the dissolved oxygen, or by a protective film over the exposed metal. As the removal of dissolved oxygen from water supplies is not usually a feasible procedure, methods of preventing corrosion of water pipes depend on the presence of a protective lining or film on interior walls of the iron pipes. New water piping usually has a protective lining of cement or an asphaltic compound. In many instances, however, the character of the water carried by the piping is such that eventually the lining disintegrates and the iron is attacked, unless the lining itself is continuously protected by a film of a mineral, usually calcium carbonate, deposited from the water. Old piping, especially piping that carries hot water, is particularly susceptible to corrosion with the production of red water. Usually, corrosion is prevented by adjusting the reaction and the calcium carbonate content of the water so that deposits of calcium carbonate on the pipe walls will form a protective film.

Most waters contain alkaline salts and these alkaline salts will form a protective coating on the pipe walls when deposition is not prevented by the presence of aggressive carbon dioxide. Carbon dioxide dissolves in water to form weak carbonic acid, increasing the hydrogen ion concentration and lowering the pH value. Where water has a relatively large carbon dioxide content, a part of the carbon dioxide is utilized to hold the calcium and magnesium bicarbonate in solution. The remainder is free and aggressive and increases the corrosiveness of the water. The aggressive carbon dioxide attacks the iron of the pipes.

In the treatment of water by rapid sand filtration, the ultimate corrosiveness of the filtered water can, in many instances, be reduced, or noncorrosive water produced, by the proper use

of chemicals in the coagulation of the water. The addition of soda ash with the alum in quantities which will produce at least 25 parts per million of excess alkalinity will, in the treatment of many waters having low alkalinity, prevent corrosion by the filtered water, provided the free carbon dioxide content is less than two parts per million. In the treatment of some water supplies, in order to neutralize the aggressive carbon dioxide, it is necessary to add more alkali than is required to produce the proper coagulation reaction. In such instances, corrosiveness can be reduced by the elimination of the carbon dioxide, by aeration of the filtered water or by application to the filtered water of either lime or soda ash.

Aeration of the filtered water is not, as a rule, a practical procedure in the operation of water purification plants. Usually, the addition of an alkali is more practical and a more efficient method of preventing corrosion than aeration. Lime is used for this purpose in most instances, as it is cheaper and generally more effective than soda ash.

Fundamentally, the amount of alkali required to prevent corrosion is governed by the alkalinity and the hydrogen ion concentration of the water. Aggressive carbon dioxide is eliminated when the pH value reaches 8.3 and alkaline waters having a pH value of 7.5 are usually but little, if at all, corrosive. In practice, the most effective method of reducing or preventing corrosion is to maintain the calcium carbonate content of water at saturation or slight supersaturation. In supersaturated water a film of calcium carbonate is deposited on the walls of the pipe which protects the underlying iron. If too much of the calcium carbonate is deposited, scale and incrustations will form, decreasing the capacity of, or possibly eventually occluding the pipe. If the water is not saturated, the iron, or a previously deposited film of calcium carbonate, will be subject to corrosion. The best results are obtained when the water is exactly saturated with calcium carbonate most of the time, with slight supersaturation from time to time.

Because of the presence of other alkaline compounds, it is difficult to determine the exact saturation point of calcium carbonate in a given water at a given time. The test best suited for this purpose is the "marble" test. The marble test is made by placing a considerable quantity, about 200 grams, of finely powdered calcium carbonate in a pyrex flask and

thoroughly washing with the water to be tested. The wash water is decanted and the flask filled with the sample water and tightly stoppered. The flask containing the sample is allowed to stand for from 24 to 48 hours, being thoroughly shaken from time to time. The total alkalinity and the pH value of the water are determined before the test is begun and again at the end of the test. If the alkalinity and the pH remain the same, the water is saturated with calcium carbonate and is noncorrosive. If the alkalinity and the pH of the sample have been increased, some of the calcium carbonate has been dissolved, indicating that the water is corrosive. If the alkalinity and pH have been reduced, the sample was supersaturated with calcium carbonate and calcium carbonate will be precipitated to form deposits, or a protective film, on the walls of the pipes. When equilibrium is established between the alkaline salts on the walls of the piping, the alkaline salts in the water, the hydrogen ion concentration and the free carbon dioxide content, corrosion does not occur because the rate of deposition of calcium carbonate on the pipe walls is the same as the rate of solution of the calcium carbonate.

If the above test shows that the calcium carbonate content of the water is below the saturation point, lime is usually added in quantity sufficient to bring it to saturation. Where alum is used as a coagulant the lime is usually added to the filtered water, but it may be applied before filtration. The methods of application are the same as those described on page 324.

In the performance of the "marble" test it is not always necessary to determine the alkalinity. The pH of the sample being tested may be determined after contact with the calcium carbonate, and if the pH has been increased, lime is added to the water supply in a quantity sufficient to produce the same pH reaction.

PURIFICATION OF TEMPORARY WATER SUPPLIES

The water supply for moving troops, for temporary camps and installations, or for troops in the theater of operations frequently must be purified under conditions which do not permit the installation of permanent or semi-permanent water purification works. The agencies employed for this purpose

are temporary or improvised facilities installed by engineer combat regiments, general service regiments, or water supply battalions, and the water sterilizing bags which are included in the organization equipment of each company or its equivalent.

Engineer water-supply battalion. The engineer water-supply battalion is an army unit and, normally, one such unit would be assigned to each field army and one to general headquarters reserve for each field army. The engineer water-supply battalion consists of a battalion headquarters, a headquarters and service company, a motor repair section and three companies, plus attached Medical Department personnel. The battalion is equipped with 9 mobile water purification units and each company is equipped with 36 water tank trucks. Each company is organized and equipped so that it has two transportation platoons, each of which has 18 water tank trucks, and a service platoon to operate a mobile water purification unit. Each water tank truck has a carrying capacity of 500 gallons. The mobile water purification unit has an average output of about 4000 gallons per hour, where the water is filtered and chlorinated. If the water is purified by chlorination alone, each unit has an average capacity of 6000 gallons per hour.

Each platoon is also equipped with canvas basins and pumps required in the storage and handling of water at water points. As the development of water supplies in the theater of operations is a function of other engineer troops, the water-supply battalion is not equipped to drill wells or undertake construction work.

Engineer general service and combat regiments. Normally, engineer general service regiments are assigned as army and corps troops. One combat regiment is assigned to each division. The combat regiments assigned to infantry divisions, and all general service regiments, are equipped with gasoline driven power pumps, hand pumps, canvas basins, hose and other water supply equipment for the development of water supplies. The combat regiment of the infantry division establishes water points or develops water sources within the divisional area to supply the organizations of the division. The general service regiments of the corps and army develop water sources and install, operate and maintain the

FIG. No. 82. Mobile water purification unit.

stationary water supply facilities in the corps and army areas. These facilities may consist of plants taken over from civilian owners, or of temporary or improvised works or appliances which vary in type, structural design, and capacity according to the existing circumstances.

The mobile water purification unit. The mobile water purification unit is a complete pressure filter plant mounted on a truck. The filter unit consists of a pressure filter in a cylindrical steel tank 42 inches in diameter and 60 inches in height. It is equipped with a five way valve which passes water to the filter, filters to waste, by-passes the water around the filter to the contact tank, washes the filter or closes the unit. The pumping unit consists of a double suction, single stage, horizontal centrifugal pump which is driven by the engine of the truck by means of a power take-off. A soda ash tank and chlorinator are connected with the suction line of the pump. An alum pot is connected with the discharge pipe of the pump between the pump and the filter. The filter is equipped with a Venturi tube and meter for measuring the rate of flow. A small laboratory is mounted on the truck in which the necessary analyses can be made (Figures No. 82 to 86).

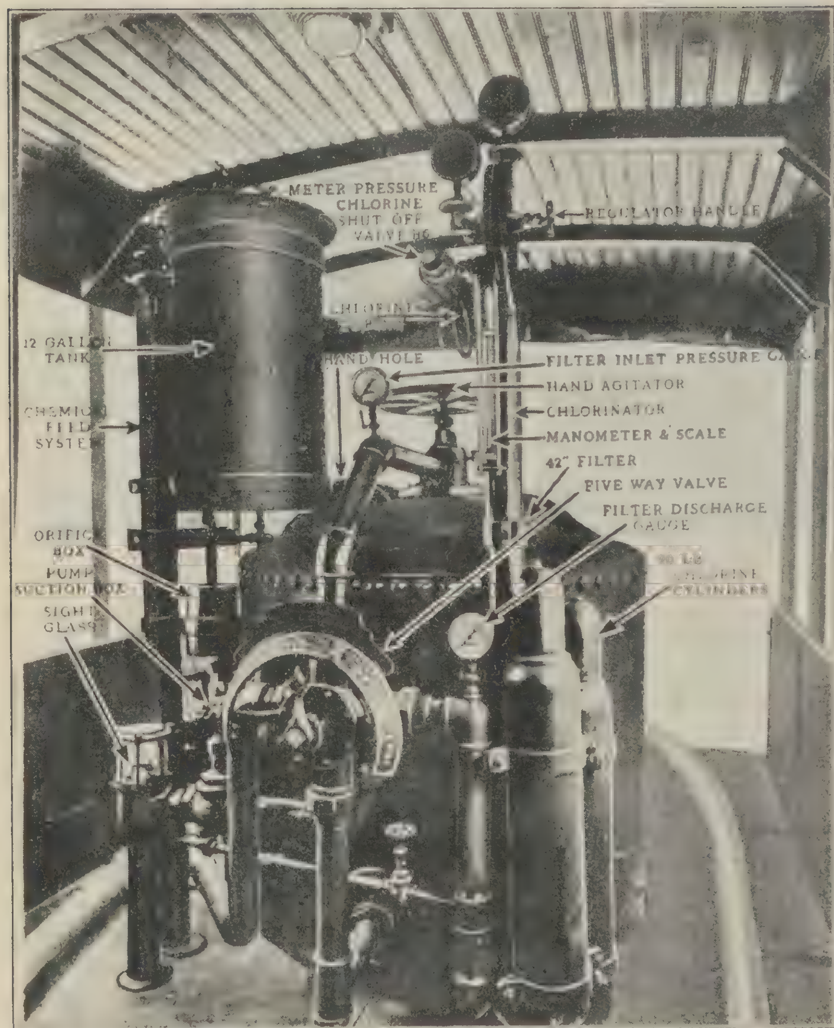


FIG. No. 83. Front view of mobile water purification unit showing five-way valve, chlorinator, tank for soda ash solution and other features.

The entire unit may be operated as a filtration plant with or without chlorination, as a chlorinating unit without filtration, or as a pumping unit without either chlorination or filtration. When in operation the truck is placed alongside of a stream or pond into which the screened end of the intake hose is dropped (Fig. No. 86).

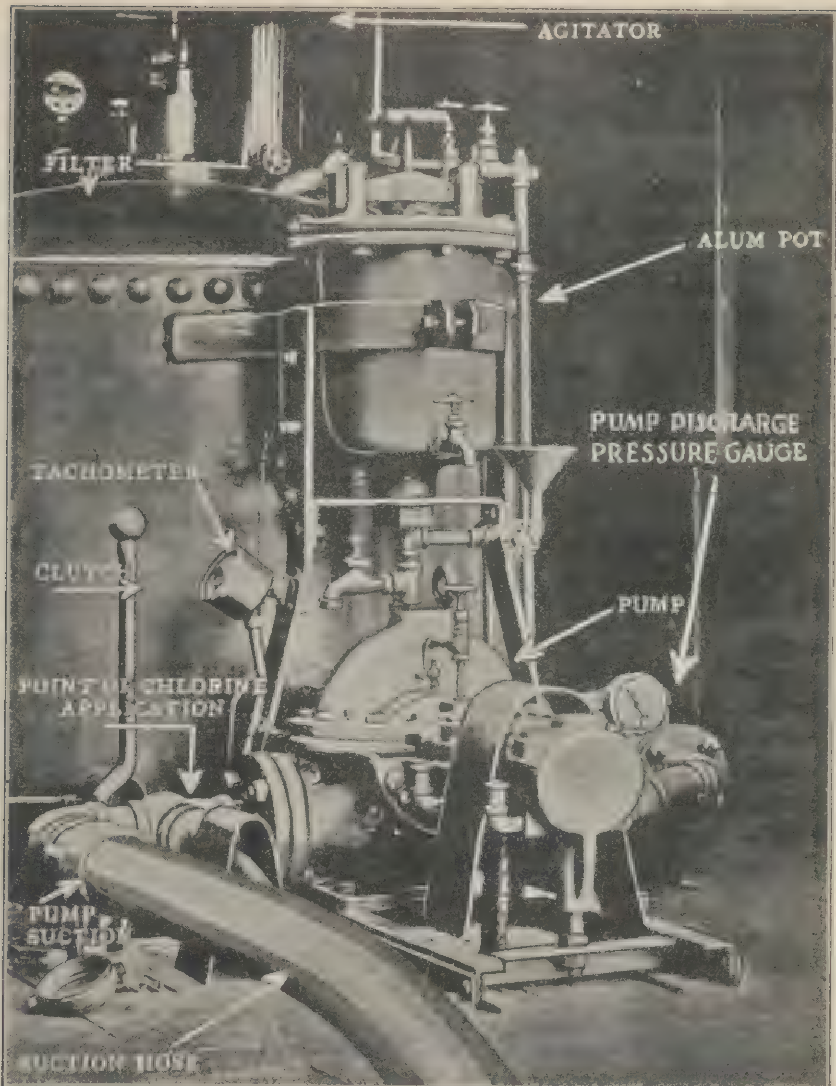


FIG. No. 84. Rear view of mobile water purification unit showing pump, power take off, alum pot and point of chlorine application.

If the water is to be filtered, the necessary chemicals are added to the water as it passes through the suction line to the pump. Liquid chlorine is applied before filtration in such quantities that the filtered water, as it leaves the filter, will contain 0.5 part per million of free chlorine. Alum is

fed from the alum pot into the discharge pipe of the pump. The filtered water should have an alkalinity of at least 10 parts per million, and if this amount is not present, the required amount of soda ash is added to the water in the suction line.

The water passes from the filter through discharge lines at both sides of the truck to the tanks of the tank trucks, to storage basins or tanks, or into water carts.

If the water is to be chlorinated only, the filter is by-passed.

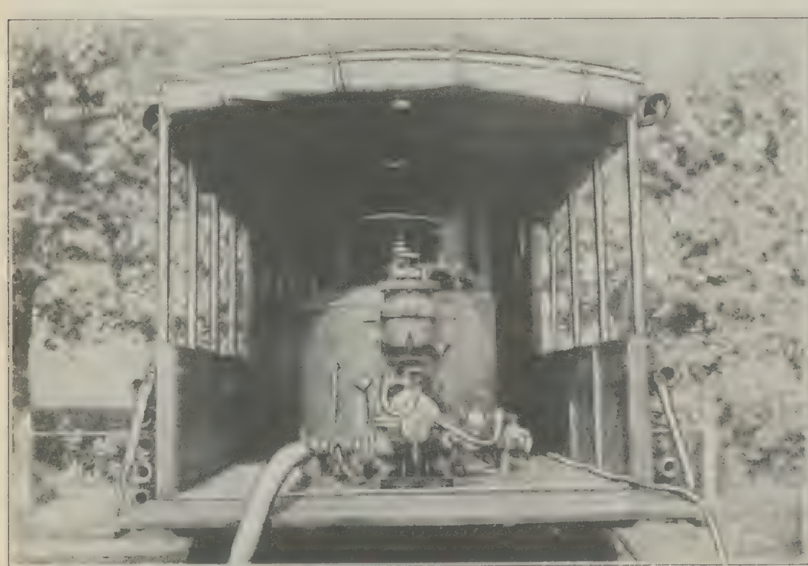


FIG. No. 85. Complete rear view of mobile water purification unit showing relation of filter to the pump, alum pot and other features.

Canvas storage basins. The standard canvas storage basin consists of a canvas-lined basin 12 feet square and from 3 to 4 feet in depth, with capacity of about 4000 gallons. Usually, an excavation of the proper size is made in the earth and the walls lined with the canvas. Where conditions are such that it is not practicable to excavate a pit, the canvas may be supported by retaining walls of earth embankments, by sand bags, or by wooden frames (Figures No. 87 and 88).

If the standard canvas sheet is not available, other canvas, or tarpaulins of various sizes, may be used. Ordinarily, canvas can be made waterproof by painting with three coats of boiling

FIG. No. 88. Mobile water purification unit showing inlet hose and the filter waste line.

tar. The cloth should be kept free from moisture until the last coat is dry and each coat should be allowed to dry thoroughly before the next is applied. Canvas basins are used to store small supplies of water at water points in the theater of operations.

The water sterilizing bag. (*Lyster bag*). The water sterilizing bag is made of heavy canvas or rubberized cloth and has a capacity of 36 gallons. Water sterilizing bags are issued to all organizations at the rate of one for each 100 men or fraction thereof (Fig. No. 89).

The water sterilizing bag is utilized primarily for the *distribution* of water previously disinfected by a water purification unit (*supra*), or otherwise. Water can be purified in a water sterilizing bag only by chlorination, and owing to the difficulty of chlorinating small quantities of water having a varying organic content, it is used for the disinfection of water only when no other facilities for obtaining purified water are available.

The purification of water in the sterilizing bag is essentially an emergency measure. The proper disinfection of water is essential in preventing disease among troops operating in the field.

FIG. No. 87. Elevated water storage tank for use in the field with the mobile purification unit. This tank holds approximately 4000 gallons of water. (Courtesy of the Engineer School, U. S. Army, Fort Belvoir, Va.).

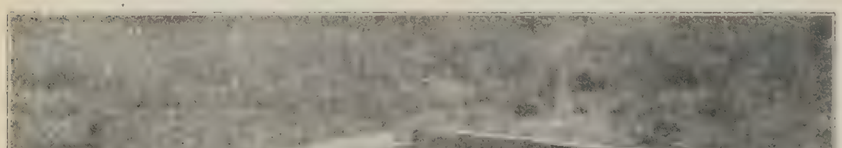


FIG. No. 88. Improvised canvas reservoir placed in pit with earthen embankment walls.

FIG. No. 89. Water sterilizing bag suspended from tripod.

FIG. No. 90. Water sterilizing bag placed in company street.

Where the water sterilizing bag must be used for this purpose, the chlorination of the water should be under the direct supervision of Medical Department personnel. Ordinarily, however, as the disinfection of the water is a function of the company concerned, the actual work of chlorination is delegated, ultimately, to the personnel of the company kitchen. Consequently, the chlorination of the water supply for the unit concerned is frequently

left to the kitchen police who, as a rule, are untrained in the technique of water chlorination. As a result, the water may be underchlorinated, and therefore contaminated, or overchlorinated to a degree which renders it nonpotable.

Water which is to be purified in a water sterilizing bag is usually obtained from nearby local sources, such as streams, ponds or wells. When obtained from a stream which is also used for watering animals, bathing, or washing clothes, the water for drinking and cooking purposes should be procured above the places where the water is utilized for other purposes. Usually, the places along a stream, where the water is to be used for the various purposes, are designated in the following order in the down stream direction and separated one from the other by at least 50 yards:

a. Water for drinking and cooking.
b. Watering animals.
c. Bathing.
d. Washing of clothes.
e. Washing of vehicles.

Each place should be marked by a suitable sign.

Purification of water in the water sterilizing bag is accomplished by means of chlorination only and, consequently, as much as practicable of the heavier suspended organic matter should be removed from the water prior to placing it in the bag. The water may be settled in a barrel, or in a pit dug at the edge of the stream or pond serving as a source of supply, or in a canvas basin. The larger particles of clay, silt and debris may be removed by straining the water into the bag through a blanket. Small pressure filters, operated by hand or by small gasoline engines, have been used to clarify water under experimental conditions. These filters will reduce the turbidity of any water supply to less than ten parts per million, which will permit effective chlorination. It is quite probable that some such apparatus will be developed for use as a part of the company equipment.

Calcium hypochlorite is used to chlorinate the water in water sterilizing bags. Both the ordinary chlorinated lime and HTH, or a similar product, are issued and utilized for this purpose. Because of their greater stability and solubility, HTH, Perchloron or like products are much more suitable than chlorinated lime for use in the water sterilizing bag (page 292). The

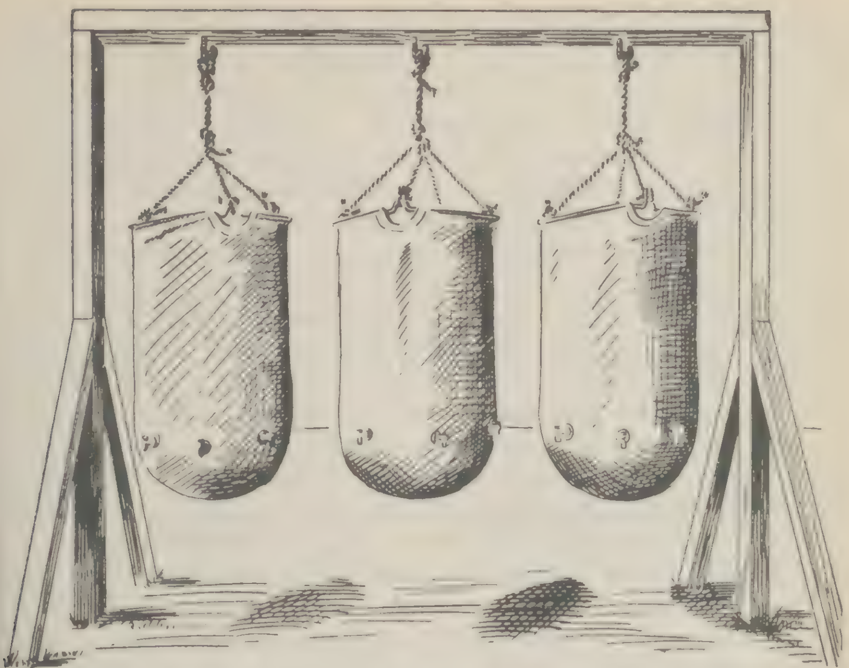


FIG. No. 91. One method of suspending water sterilizing bags.

calcium hypochlorite is usually issued in glass ampules, the chlorinated lime in one gram and the HTH in approximately one-half gram ampules. One gram of the chlorinated lime containing 35 per cent of available chlorine, or one-half gram of the HTH, or a similar compound containing 70 per cent of available chlorine will yield approximately 2.5 parts per million of free chlorine when added to a bagful of water. Usually, however, as the water is more or less turbid and the chlorinated lime contains less than 35 per cent of available chlorine, the residual chlorine in the treated water varies from 0.5 to 1.5 to 2 parts per million. This quantity of chlorine will frequently produce a marked taste, and in the presence of organic matter it may cause a decidedly objectionable taste.

The chlorination of water in the water sterilizing bag must be carried out by company personnel, and frequently by men who have had very little training in this kind of work. The water to be treated in sterilizing bags is, as a rule, heavily contaminated and contains varying quantities of organic matter.

Under these conditions it cannot be expected that the results will be entirely satisfactory. At times the water is over treated to an extent that renders it nonpotable, or is insufficiently treated and remains contaminated. In order to insure that the water is rendered safe despite these adverse factors, the methods used are designed to overchlorinate within the limits of potability and the contact period is lengthened.

The routine technique used in the chlorination of water in a water sterilizing bag is as follows:

1. Fill the bag to the 36 gallon mark, or if this mark is not present, to within four inches of the top.
2. Draw a small quantity of water through one of the faucets into a canteen cup.
3. Break an ampule of the calcium hypochlorite into the water in the cup and with a clean stick rub it into a thin paste containing no visible lumps. Then add sufficient water to fill the cup two-thirds full.
4. Empty the solution of calcium hypochlorite in the cup into the water in the bag and stir thoroughly with a clean stick which is long enough to reach the bottom of the bag. Then flush out each of the faucets.
5. After the calcium hypochlorite has been in contact with the water in the bag for at least ten minutes, wash out one of the faucets by allowing a small amount of water to run through it onto the ground. Then fill a clean cup about two-thirds full of water from the same faucet.
6. Add one c.c. (approximately 15 drops) of the orthotolidine solution to the water in the cup and allow it to stand for about five minutes so that the color will develop. Because of the reflected light, the color of the water in the cup is more intense than it would be if the same water were placed in a glass tube. A well marked yellow color indicates that the water contains about the proper amount of residual chlorine. An orange color is evidence of overchlorination.
7. If no residual chlorine is present at the end of the ten minute contact period, the chlorination procedure, as outlined above, is repeated. Where it is suspected that the calcium hypochlorite is inert, a preliminary

test with orthotolidine should be made immediately after the addition of the calcium hypochlorite solution to determine if the water contains any free chlorine at that time.

8. As a factor of safety, the water should be allowed to stand for twenty minutes after the end of the contact period, or for thirty minutes after the addition of the calcium hypochlorite, before being used for drinking purposes.

The method of chlorinating water in a sterilizing bag is necessarily subject to variations to meet existing conditions. Obviously, when such a large quantity of chlorine is added to water containing organic compounds tastes may be produced which are so objectionable that the troops will not drink the water if any other supply is available. Dechlorination of water in the field with sodium thiosulphate, or otherwise, is a dangerous procedure and should be employed only when absolutely necessary to remove tastes and odors from the water, and then only under strict supervision of a competent officer or noncommissioned officer. Dechlorination removes the residual chlorine which serves to protect the water in the bag against recontamination by the hands of those using the water, by dust or by other agencies. Also, where dechlorination is practiced there is frequently a tendency to shorten the contact period and to dechlorinate the water before disinfection is complete.

The greater stability of HTH and Perchloron, as compared with ordinary chlorinated lime, renders it desirable and practicable to vary the quantity of calcium hypochlorite inversely with the turbidity. In order to prevent overchlorination to a degree which will render the water nonpotable because of objectionable tastes, only a part of the calcium hypochlorite in the glass ampule is added to the water having relatively low turbidity. The orthotolidine test, as described above, is then made at the end of the usual ten minute contact period to determine if sufficient residual chlorine is present. Frequently, one-fourth to one-half of the contents of the ampule will suffice to disinfect the water. If the test shows that the residual chlorine content is insufficient, a part of or all the calcium hypochlorite remaining in the ampule is added to the water, and the orthotolidine test repeated after another ten minute contact period.

In case the water is overchlorinated to a degree which renders it nonpotable, the bag should be emptied and refilled. The water is then chlorinated with a smaller amount of the calcium hypochlorite.

Under suitable conditions and provided that chlorination is properly carried out, a contact period of ten minutes would accomplish disinfection. However, as previously discussed (page 346), because of the adverse conditions under which the water sterilizing bags are used, a longer contact period should be allowed to insure that the water is actually disinfected when consumed by the troops. Experience has demonstrated that, as a general rule, the water should be in contact with the chlorine for thirty minutes before being released for consumption.

Other emergency measures. If water sterilizing bags are not available, the water may be chlorinated in other containers, such as galvanized iron cans, pails or barrels. A proportional amount of calcium hypochlorite is used and the method of chlorination is the same as with the water sterilizing bag.

If larger containers are not available, canteens may be utilized. One gram of chlorinated lime or one-half gram of Grade A calcium hypochlorite is dissolved in a canteen of water. This strong solution is then used to purify water in other canteens. The cap of a canteen is used as a measure and one canteen capful of the strong solution is added to each canteenful of water to be treated. The water should be well shaken and not used until thirty minutes after chlorination.

Iodine may be employed as a disinfectant instead of chlorine. Ten c.c. of the tincture of iodine are used to disinfect a water sterilizing bagful of water (36 gallons). Two or three drops are used to disinfect a canteenful of water. Iodine is expensive and the supply would be limited during war. Further, in the treatment of some waters, iodine is apparently much less effective than chlorine. The water should not be used until thirty minutes after the iodine has been added.

If calcium hypochlorite or iodine is not available, water may be purified by boiling for ten minutes. This method should not be used, if avoidable, by the individual soldier, but the water should be boiled under supervision in comparatively large quantities and then distributed to the troops. Water may be boiled in galvanized iron cans if they are avail-

able. Aeration of the water by pouring it through the air from one receptacle into another will eliminate the flat taste due to boiling.

DISTRIBUTION SYSTEMS

The distribution system for a permanent water supply includes the pipes, reservoirs, tanks, and pumps used to transport the water from the place of purification to the place of consumption. The pipes are ordinarily made of cast iron but may be made of wooden staves which are wrapped and held in position by wire. Wooden pipes are commonly installed only under circumstances which render iron difficult to procure, as in the event of a major war. The pipes of a permanent water supply system are laid under ground, usually below the normal frost line. In addition to the pipes, distribution reservoirs or tanks used for storage, or to equalize the flow, may constitute a part of the distributing system. Pumps are used in a distributing system to elevate the water to a higher level for subsequent distribution by gravity, or to increase the pressure.

In some instances, two separate water supplies are connected to the same distribution system. One supply, the primary supply, is normally used for drinking and for other domestic purposes, while the other, the secondary supply, is used in an emergency, such as for fire fighting, or for industrial purposes. The primary supply is purified and the secondary may be purified but frequently is contaminated. While under normal conditions the secondary supply is prevented by check valves of different kinds from entering the primary distribution system through cross connections, nevertheless there is always danger that the secondary supply will contaminate the primary supply through defective valves. All such cross connections should be eliminated.

From a sanitary point of view the distribution system is important because of the opportunities offered for bacterial recontamination of the water subsequent to purification and prior to delivery to the troops.

Bacterial contamination of water in the distributing system. The average pressure in the water pipes and mains of a distribution system varies from 40 to 90 pounds per square

inch and, as the internal pressure is greater than the external, contaminated surface water cannot enter the pipes as long as the pressure is maintained. However, when the internal and external pressures are equalized by the closure of valves, by placing a portion of the distributing system out of service, or by cutting out a reservoir, water containing contamination may enter and contaminate the water in the pipes. When the water is again turned on, this contaminated water will be delivered to the consumer. In cases where the water is shut off so that breaks or other defects in the pipes can be repaired, contaminated water may enter the pipe through the defect in question or through other undetected and sometimes much smaller apertures in the walls of the pipe.

The check valves which serve to separate a purified primary water supply from a secondary and contaminated supply may leak or be left partially opened, and thus permit the contamination of the water in the primary supply.

When sections of new pipe lines are placed in a distribution system, contaminated material, such as soil or surface water may enter the new pipes before the connections are closed. If service is begun or resumed without prior disinfection of the new pipes, the water delivered to the consumer may be contaminated.

Contaminated surface water may enter an inadequately protected distributing reservoir where the level of the water in the reservoir is below the level of the surface water. Birds and insects may gain access to and contaminate the water in uncovered tanks or reservoirs or, if covered, through unscreened openings.

Contamination may enter the water in the distributing system at a pumping station through a leaking suction pipe, or in priming water, if contaminated water is used for priming. Contaminated surface water may enter an inadequately protected suction well through defects in the walls or in backflow from drains.

Protection of the water in the distributing system from contamination. When the pressure within a pipe line has been reduced or removed, and it is known or suspected that the pipes are defective, or where pipes have been repaired or new sections installed, the portion of the pipe line concerned should be disinfected before service is resumed.

Disinfection of a pipe line is accomplished by first isolating the section involved by closing the gate valves on the main line. The isolated section may be thoroughly flushed by opening one of the valves connecting it with the live portion of the system and flushing through an open fire hydrant at the cther end of the isolated section. A fire hydrant at one end of the isolated section may be connected by means of a fire hose with a hydrant on the live section and the isolated section flushed through an open fire hydrant at the other end. The flushing removes most of the organic material which would interfere with chlorination. When the flushing water is shut off, the main is drained of as much of the remaining water as possible, and the outlet hydrant closed.

Chlorine, either in the form of liquid chlorine or calcium hypochlorite, is used as a disinfectant. A chlorinator for applying a solution of either liquid chlorine or calcium hypochlorite may be tapped into the main, using an injector if necessary. Dry chlorine gas may be applied through a diffuser in the main. At least one part per million of chlorine should be used. The chlorinated water is allowed to stand in the pipes for from three to twenty-four hours and is then flushed out (Fig. No. 92).

In laying new or repairing old pipes, care should be taken to prevent dirt, silt or other material from entering or remaining in the pipes. In some instances, in order to avoid the use of a chlorinator, the pipes may be disinfected by placing about one ounce of calcium hypochlorite in each section of the pipe as it is laid. When the work is completed the isolated section is filled with water from the live system without prior flushing. The calcium hypochlorite is dissolved and the chlorinated water is allowed to stand in the pipes for several hours, after which it is thoroughly flushed out. As calcium hypochlorite decomposes rapidly when exposed to the air, and as organic matter reduces the bacteriolytic power of the chlorine, this method is effective only when the work of laying or repairing the pipes can be completed within a short time and where the accumulation of an undue quantity of dirt in the pipes can be prevented.

No cross connections between a purified primary supply and a contaminated secondary supply should be permitted in a distribution system that is operated under military juris-

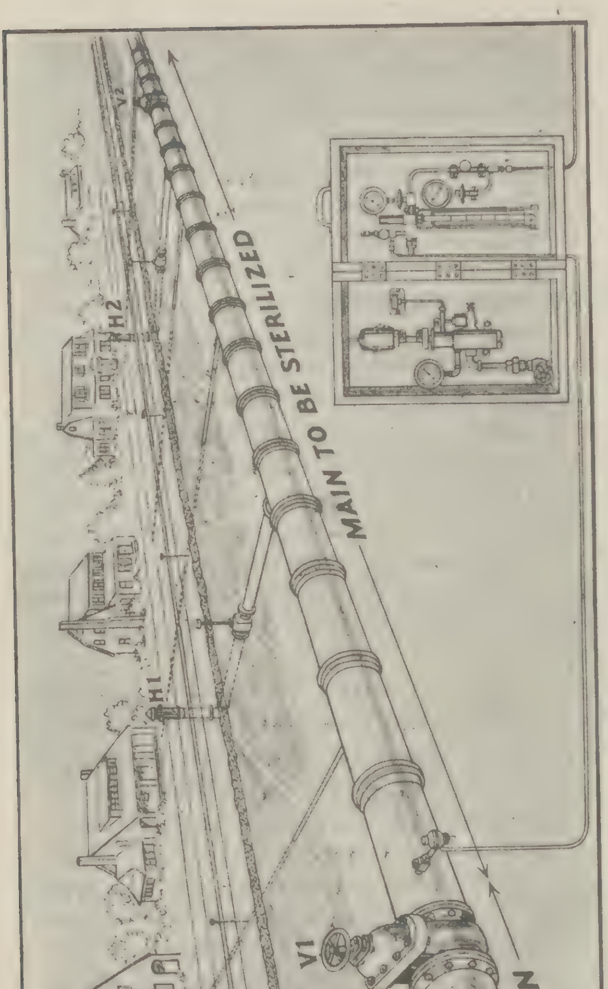


FIG. No. 92. Method of using portable chlorinator in the disinfection of a recently installed section of water main. (Courtesy of the Wallace and Tiernan Co., Inc., Newark, N. J.).

diction. The secondary supply should either be purified or entirely separated from the primary supply.

The contamination of the water in reservoirs or tanks is prevented by the correction of structural defects which permit the entrance of surface water, or access to the water by animals, birds or insects, and by measures which will protect the water against accidental or wilful contamination by man.

Detection of leaks in pipes. Breaks in water pipes or large leaks are usually evidenced by the appearance of water on the surface of the ground. At times, however, leaks may exist where the escaping water drains away into the surrounding soil or reaches a sewer line, stream or other body of water, with no evidence of the leak apparent at the surface of the ground. Under these circumstances, if the water pressure in the pipes is reduced sufficiently, contaminated surface water may enter through the defects causing these small undetected leaks.

Several methods of testing water pipes for leakage are available. The hose and meter method is the simplest procedure for determining hidden leakage where only a small distribution system or a few sections are to be tested. This test should be made when the normal consumption rate is at a minimum, which is usually between the hours of midnight and 4:00 A.M.

The section to be tested is isolated from the rest of the distribution system by closing the gate valves on the main, care being taken that the valves used for this purpose are tight. A fire hydrant on the isolated section is connected with a hydrant on a proximal live section by means of a fire hose, and a compound water meter is set in the hose line. If water is flowing out of the isolated section, there will be a flow of water from the live section through the fire hose into the isolated section which will be indicated and measured by the meter. If the flow due to the legitimate use and wastage from plumbing fixtures or through defective valves is excluded, all the remaining flow is caused by leakage through the pipe walls.

Where extensive surveys for water leakage or wastage are made, special instruments, such as a pitometer or an aqua-

phone, are usually employed. These devices give satisfactory results only when operated by personnel skilled in their use.

Distribution of a temporary water supply. During peace, and in the zone of the interior in war, the water supply for temporary camps and installations, for troops in bivouac and for moving troops is normally distributed by temporary pipe lines and reservoirs, by water carts, or by water sterilizing bags. In the theater of operations, additional distributing facilities, such as water tank trucks and railway tank cars, are furnished by engineer troops.

Pipe lines. A temporary water supply may be distributed through sub-surface or surface pipes. Pipes may be laid in forward areas of the theater of operations but, ordinarily, the military situation will not permit pipe lines to approach closer than 5000 yards of the front line. These pipe lines may be placed underground where protection from freezing, shell fire or traffic is essential. In a temporary camp, water may be distributed to selected points throughout the camp area by pipes laid on top of the ground.

The pipes employed for the distribution of a temporary water supply are subject to the same sources of contamination as are the pipes which carry the water of a permanent supply.

FIG. No. 93. Trailer water cart, 300 gallon capacity.

Water carts. Where required, a company or detachment of troops is provided with a water cart. These carts vary in capacity from the 110-gallon animal drawn cart to the 300-gallon trailer cart. Water carts are employed to transport and distribute treated or untreated water directly from the source of supply to kitchens and water sterilizing bags, or purified water from water distributing points to the place of issue to the troops. Cans, such as milk cans or similar containers may be used instead of tank carts.

Water may be chlorinated in the water cart tanks by the application of a suitable amount of calcium hypochlorite, using the technique employed in the chlorination of water in water sterilizing bags (page 346).

FIG. No. 94. Animal drawn water cart, 110 gallon capacity.

Water sterilizing bags. Water sterilizing bags are utilized as agencies for distributing water to the troops, as well as containers for water which is to be chlorinated. Purified water which has been transported from a water point may be placed in water sterilizing bags for final distribution. Unpurified water may be transferred from a source of supply by a water cart,

or in pails or cans, to water sterilizing bags for distribution after chlorination.

Water tank trucks. The water tank trucks of the engineer water supply battalion are usually used to transport water from the place where it is purified to water points in the forward areas.

FIG. No. 95. Motor drawn water cart placed near company kitchen. The water in the cart has been chlorinated and is being used for cooking and other purposes about the kitchen.

Railway tank cars. Railway tank cars of different capacities, operated over light or standard gauge tracks, may be utilized to transport water for comparatively long distances. The water may be delivered in the tank cars directly to a water point or it may be transferred to tank trucks which distribute it to water points.

Water distributing points. Water distributing points are designated places where water is stored and distributed to organizations. They are located as near the organizations which are to be supplied from them as the military situation and the road net will permit. Frequently, they are located near the ration distributing points. A typical water distributing point in a forward area is equipped with canvas basins for the temporary

FIG. No. 96. Water distributing point, showing canvas basin and method of filling water cart with hand operated pump.

FIG. No. 97. Mobile water purification unit set up to supply a water distributing point.

storage of water, hand pumps or small power pumps for transferring water to the tanks of water carts, and facilities for filling canteens and watering animals. Purified water for a water distributing point may be supplied by a mobile water purification unit, in which case the distributing point is either at a source of supply, or the water is carried forward from the water puri-

fication unit in the rear to a forward water distributing point by water tank trucks, by pipe lines, or by railway tank cars.

In stable positions, or in rear areas, water may be stored at water distributing points in wood, steel or concrete tanks.

Water is distributed from a water distributing point to organizations by the organization water carts or water cans. Organizations are responsible for the proper care of the water beyond the water distributing point. The water may be recontaminated after it has been removed from the water distributing point by dirty containers or by improper handling while being transferred from the water cart or cans to water sterilizing bags or canteens.

LABORATORY ANALYSIS

Water is analyzed, both bacteriologically and chemically, to determine the presence of contamination which will influence, directly or indirectly, the potability of the water.

During peace, and in the zone of the interior in war, laboratory analyses of water are made by corps area and department laboratories, hospital laboratories, the Army Medical School and such other laboratories as may be established in war. In the theater of operations, water analyses are made by the laboratory section of the service company of the medical regiment, army laboratories and communications zone laboratories.

Bacteriological analysis. The bacteriological examination of water is made for the purpose of determining the presence of human excreta. As the pathogenic bacteria that are discharged from the body in the excreta are difficult to isolate from water, the technique employed in the performance of the tests is designed to detect the presence of the coliform group of organisms. The coliform organisms are found normally in discharges from the intestinal tract of man, animals or birds. However, in practical work, if the coliform group of organisms is present in water, it is presumed, unless proven otherwise, that the water is contaminated with human excreta. Water contaminated with human excreta is considered to be dangerous to the health of man, when used without purification for drinking or cooking purposes, because of the possibility that it may contain pathogenic organisms derived from the excreta.

It is possible that water may be so slightly contaminated with human excreta that only an occasional sample will contain the coliform group of organisms and, as the chances are remote that such water will transmit disease-producing organisms to the consumer, it may be regarded as a safe supply for drinking and cooking. Consequently, it is necessary that a standard of bacteriological quality be employed which indicates the maximum amount of contamination which water may contain and still be regarded as a safe supply. The standard generally recognized in water purification practice is that adopted by the Treasury Department on June 20, 1925, relative to the purity of the water supplied by common carriers in interstate commerce.

Treasury Department Standard

1. A standard portion of water to be tested shall be ten cubic centimeters.
2. A standard sample of water to be tested shall consist of five standard portions of ten cubic centimeters each.
3. Of all the standard portions examined not more than 10 per cent shall show the presence of the coliform group of organisms.
4. Occasionally three or more of the five equal portions constituting a single standard sample may show the presence of the coliform group of organisms. This shall not be allowed if it occurs in more than:-
   a. Five per cent of the standard samples when twenty or more samples have been examined.
   b. One standard sample when less than twenty samples have been examined.
5. In the examination of any water supply the series of samples must conform to both the above requirements (3 and 4). For example, where the total number of samples is less than six, the occurrence of positive tests in three or more of the five portions of any single sample, although it would be permitted under requirement 4 above, would constitute a failure to meet requirement 3 above.
6. The coliform group of organisms includes all gram negative non-sporeforming bacilli which ferment lactose

with gas formation and grow aerobically on standard solid media.

7. The procedures used to demonstrate the presence of organisms of the coliform group shall be those prescribed in Standard Methods of Water Analysis (8th Ed. 1936) for the completed test.

Interpretation of reports of bacteriological analysis. Members of the coliform group of organisms found in water are presumed to have been derived from human excreta unless there is proof to the contrary. If coliform organisms are present, it is possible that pathogenic organisms derived from the same source as the coliform organisms, but not demonstrable by routine laboratory procedures, are also present.

Where a survey of a water supply system reveals existing actual or potential sources of contamination, a positive bacteriological report is valuable confirmatory evidence, but a negative report does not necessarily indicate that the water is potable. The absence of the coliform group of organisms from the analyzed sample indicates only that the particular sample tested, or that the water supply at the particular time that the sample was taken, did not contain excreta. In the presence of known actual or probable sources of contamination, as shown by a sanitary survey, a negative bacteriological report does not justify the assumption that such sources do not intermittently or regularly contaminate the water. If the results of a water survey are positive and those of the laboratory analysis are negative for contamination, the survey findings should be accepted, unless a series of bacteriological analyses supported by confirmatory observation on the ground show that the suspected sources of contamination do not actually contribute contamination to the water supply.

Frequency of bacteriological analysis. In the case of permanent water purification plants which are operated or supervised by the army, samples of the purified water should be taken for bacteriological analysis at least once a day as one of the routine procedures for determining the efficiency of the plant. If water is supplied by a civilian plant which is properly operated, water from the distribution system should be bacteriologically analyzed at least once a month in an army laboratory. If the water is known to be suspected of being subject to contamination,

samples for bacteriological analysis should be taken from the distribution system at daily to weekly intervals.

In the purification of temporary water supplies by means of the mobile water purification unit, water sterilizing bag, or improvised appliances, bacteriological purity is produced by an excess of chlorine in the water (page 291). Bacteriological analysis is, however, utilized to determine the efficiency of the purification measures employed and should be made at such intervals as the circumstances require and will permit.

Methods of reporting. Regardless of the standard employed or the kind of report form used, every report of the bacteriological examination of water should state definitely whether or not the water examined is potable bacteriologically. Where the results of the examination are doubtful, the report should be on the side of safety and state that the water is not potable bacteriologically, but should be reexamined. The Army Medical School laboratories use one of the following statements in reporting the results of the examination of each sample of water, and it has been found that such a report meets the requirements of those responsible for water supplies in the field.

1. Potable bacteriologically. No evidence of contamination has been found.
2. Not potable bacteriologically. Tests reveal evidence of contamination.
3. Not potable bacteriologically. Colony count is too high; suggest reexamination.

The number and size of the portions tested agree with the requirements of the Treasury Standard. Report number 1 means a completely negative result, that is, no evidence of the coliform organisms has been found. Report number 2 means that one or more of the series of standard lactose broth fermentation tubes in the test shows the presence of coliform organisms. Report number 3 is rendered when there is a completely negative result in so far as the coliform group is concerned, but the plain agar plate count indicates the presence of more than 200 bacteria per c.c. In the latter instances, the water is considered to be potentially contaminated, and the reason for the high colony count should be determined immediately. It may be due to an unsterilized sample bottle,

poor technique in the collection of the sample, or to actual contamination of the water supply.

Chemical analysis. From the viewpoint of purification procedures the most important chemical analysis of water is that which is made for the purpose of determining the hardness content. The presence of nitrogen compounds or chlorides as revealed by a chemical analysis may indicate contamination with sewage, but such contamination is more effectively demonstrated by a bacteriological test for the coliform group of organisms. At times it may be necessary to determine the quantity of iron in a sample of water by chemical analysis. Occasionally, water is chemically analyzed for the presence of such compounds as the salts of lead, copper, zinc or sulphur.

Samples. Samples of water for bacteriological analysis should be collected in sterilized, glass stoppered bottles holding from 100 to 250 c.c. Prior to sterilization, the stopper should be covered with a cloth secured by a wire or string tied around the neck of the bottle for the purpose of holding the stopper in place and preventing the contamination of the lip of the bottle subsequent to sterilization. Care should be exercised that the cloth around the stopper of the bottle and the stopper are not removed, except for the purpose of filling the bottle with the water to be analyzed. In handling the bottle, and in taking the sample, nothing must be allowed to touch the lip of the bottle or that part of the stopper which is inserted into the neck of the bottle. After the sample is obtained, the stopper is replaced and covered with the cloth which is securely fastened by a string or wire around the neck of the bottle.

In taking a sample from a faucet or pump, the water is allowed to flow for a few minutes and then a small stream is directed into the sample bottle in such a way that the water does not come in contact with the lip of the bottle.

A sample is obtained from a spring, an open well, lake or pond by placing the bottle, with the stopper removed, in a close-fitting basket made of string or wire with a weight at the bottom and lowering the bottle into the water until the mouth is at least six inches below the surface.

A sample may be obtained from a stream by immersing the bottle below the surface of the water in a horizontal position with the open mouth up-stream.

At least one quart, or preferably two quarts, of water should be obtained for chemical analysis. The samples should be collected in chemically clean, glass bottles or jars.

The bacteriological analysis of a sample of water should, if practicable, be started within six hours after collection, but in any event not more than twelve hours should elapse between the collection of the sample and the beginning of the analysis. Where practicable, the sample should be kept at a temperature of from 6°C. (42.8°F.) to 10°C. (50°F.) during storage and transportation.

Where a sample of water is to be subjected to chemical analysis the time which may be allowed to elapse between collection and the beginning of the analysis depends upon the character of the water and the kind of analysis that is to be made. If the degree of hardness alone is to be determined, the storage of the water in the sample bottle for a reasonable length of time will have no appreciable influence on the results of the analysis. If the chemical analysis is to be made for the purpose of determining the content of chemical compounds the nature of which is influenced by the activities of the organisms present, such as the nitrogen compounds, the length of time intervening between the collection and analysis of the sample will influence the results. Under these conditions not more than 48 hours should be allowed to elapse between the collection of the sample and beginning of the analysis.

The samples may be transported by mail, express, or courier. The bottles containing samples for bacteriological tests may be packed in mailing tubes or other similar containers. The larger bottles containing water for chemical analysis should be packed in boxes in such a way as to preclude breakage enroute.

QUANTITY OF WATER REQUIRED

The quantity of water required varies within limits according to the existing conditions. The amount actually required to sustain life and permit physical activity over a short period of time is much less than the quantity which will be consumed by men and animals, plus that used by the various facilities, when the supply is ample and the distribution is unhampered. Consequently, the amount of water per man which should be supplied in permanent camps and stations is very much greater than the minimum

quantity which must be furnished troops engaged in actual combat. Climatic conditions also influence the consumption rate, which is much higher during the hot summer months, or in the tropics, than during the winter time or in temperate climates.

In permanent camps and stations. In permanent camps, a varying amount of water is lost through avoidable and unavoidable wastage. This wastage is due to leaking mains, to the wastage of water at the faucets or through plumbing fixtures, or to the use of unnecessarily large quantities where smaller amounts would suffice. Given an ample supply, with no undue restrictions on the use of water and with average wastage, the quantity of water consumed in a permanent camp or station will vary from 50 to 75 gallons per person per day. This includes that used for all purposes, such as for drinking, cooking, laundering, bathing, for a water carriage sewerage system and for animals. In a permanent station during peace, wastage from the mains, the operation of comparatively large shops, garages and laundries, together with lax water discipline, may result in the consumption rate being as high as 200 gallons per capita per day. In a camp where relatively little water is used by utilities and where regulations are promulgated and enforced to prevent wastage, the consumption rate may be as low as 30 gallons per capita per day.

In semi-permanent or temporary camps. In camps having a temporary water supply system where the water is distributed by pipes, the quantity of water consumed will vary from 25 to 35 gallons per capita per day. This includes the water supplied for baths and animals.

Where water must be distributed by trucks or water carts, particularly in temporary camps, about five gallons are required per man per day for drinking, cooking and washing. If watering troughs for animals are supplied, about ten gallons per animal per day are required.

In bivouac or for marching. Troops in bivouac or marching require two gallons per day per man for drinking, cooking, and washing of hands and faces, and ten gallons per day for animals.

In combat. In combat, under average conditions, physical efficiency can be maintained for a period of not more than three days if from three pints to two quarts of water per

day are supplied to each man. Under like conditions, animals require from three to five gallons per day.

SANITARY SURVEYS OF SOURCES AND INSTALLATIONS

A sanitary survey may be made of permanent water supply systems for stations, camps and fixed installations. Or a survey may be made of the sources, methods of purification, transportation or distribution of water for temporary camps or installations, or for moving troops.

A sanitary survey includes an inspection and study of all phases of the water supply for the purpose of detecting and making recommendations for the correction of conditions or defects which actually or potentially endanger the health of the consumers.

Survey of permanent water supply system for a station, camp, or fixed installation. The source of the water for a permanent water supply system may be ground water obtained from a spring or well, or it may be surface water from a stream, lake, or pond. If the water is derived from a deep well, it may be delivered to the troops without treatment. In the case of water from other sources, it may be purified by chlorination alone, by filtration and chlorination, or by sedimentation and chlorination. The distribution system may be extensive and complicated, or it may be simple in design. The water supply system may be owned and operated by a municipality, by private citizens, or by military authorities. The survey includes inspection of the source of raw water for sources of bacterial contamination; of the purification facilities for defects in operation or construction which endanger or impair the efficiency of the purification procedures, and of the distribution system for existing or potential defects or conditions which permit, or which might result in recontamination of the water subsequent to purification and prior to consumption.

Survey of the source of the water supply. Ground water may contain contamination consisting of impurities which it received before entering the ground and which are not removed by filtration through the soil before the water is recovered in a well or spring. Also, surface water may carry contamination into an otherwise pure ground water supply in

the well or spring. Consequently, the nature of the terrain, the extent and direction of surface drainage, the geology, and the proximity of human habitation are factors which should be considered in the inspection of a ground water supply.

Surface water obtained from an inhabited watershed should be regarded as contaminated regardless of whether or not a survey of the source of supply shows that visible sources of contamination are present and even though the results of the laboratory analysis of the water for the coliform group of organisms are negative. Surface water, as a general rule, is subject to contamination at any time, although it may be free from contamination at the time the survey is made and samples are taken for examination. A survey of the source of a surface water supply is made, not to determine merely if the water is contaminated, but to ascertain the sources of contamination and provide for their elimination or control. A reduction in the amount of contamination in the raw water serves to lessen the danger that disease producing organisms will escape destruction by the purification procedures and remain in the water delivered to troops.

The type of surface water which constitutes the source, that is, a stream, lake or pond, should also be considered with regard to such physical characteristics as currents, turbidity, dry weather flow, susceptibility to flooding, shallow areas, or the presence of aquatic vegetation.

Protection of the water in a well or spring. In inspecting any well, deep or shallow, it should be determined if there are defects in the casing of the well which will permit the entrance of contaminated surface water. It should also be noted whether the top of the well or the pump pit is so protected that surface water cannot reach the water in the well. The depth of the strainers in driven or drilled wells and the depth of the water in dug wells should be ascertained in order to determine if surface water from the immediate vicinity of the well can reach the water in the well before contamination has been removed by filtration through the soil.

If a spring is provided with a basin or reservoir, it should be inspected to determine if the walls and bottom are sufficiently water tight to prevent the entrance of surface water. The effectiveness of any ditches, embankments or retaining walls which have been installed to prevent surface water from

entering the spring, should likewise be determined by inspection. If the spring is a gravity spring, the nature of the terrain in the immediate vicinity should be investigated for conditions which would permit contaminated surface water to reach the ground water table.

Survey of rapid sand filtration plant. The capacity of the coagulation basins, the turbidity of the raw water, the rate of flow, the period of detention, and the depth of the sludge deposited in the bottom of the basins should be noted. The kind and quantity of coagulants added to the water, the thoroughness with which the chemicals are mixed with the water, the size and character of the floc and the alkalinity of the water before and after the addition of the coagulant, should be determined. Any factors which might interfere with sedimentation and clarification by increasing or decreasing the rate of flow through the settling basins, or produce short circuits in the flow, should be sought.

The rate of filtration and the methods and appliances used to control the rate should be noted. The capacity of the plant, the average consumption rate, and the time of occurrence and extent of the peak loads should be considered, and the relation of these factors to the efficiency of the plant determined. If necessary, a filter unit should be drained to below the surface of the sand and the condition of the sand investigated. The method of washing the filter should be observed and the defects, if any, should be noted.

Chlorinating plant. The amount of chlorine added, the method of application and the efficiency of such method should be considered. The amount of free chlorine in the water at different stages of the process should be determined. Particular attention should be given to any deficiency or excess of residual chlorine in the filtered water, to the regularity of application, and to the condition and suitability of the chlorinating apparatus, including the ammoniating apparatus if the ammonia-chlorine process is used. Where the water is treated by chlorination alone, a careful study should be made of the methods of applying the chlorine, the regularity of application, the effect of variations in the turbidity of the raw water on the efficacy of the chlorination, and the measures utilized to determine the efficiency of the chlorination in the purification of the water.

Filtered water reservoirs. Defects in the location and structure of the filtered water reservoirs should be noted with a view to determining the liability of the water to contamination by ground water or surface water. If the level of the water in the reservoir is below the level of the ground water, the latter may seep through defects in the walls into the filtered water. Surface water may enter the reservoir through or over the walls above the level of the water in the reservoir. The protection afforded the water in the reservoir against contamination by man or animals should also be ascertained.

Laboratory analysis. The efficiency of the purification plant is determined by the results of bacteriological analysis of the purified water. The method of obtaining samples and the frequency of the bacteriological examinations should be ascertained. The results of routine bacteriological examinations made prior to the survey should be studied to determine variations in the quality of the water and the average efficiency of the plant.

If required, the degree of hardness may be determined by chemical analysis. The amount of turbidity and color in the water at any stage of the purification process may be determined by tests made during the survey.

Method of conducting a survey of rapid sand filter plant. The survey of a water purification plant should be conducted in a systematic manner and in accordance with a preconceived plan. The survey may be partial or complete, depending on the circumstances and the nature of the defects sought. In the conduct of a complete survey of a plant, ordinarily, the best results can be obtained by starting with the source of the raw water and inspecting in sequence each part of the plant. Appendix I shows factors that should be considered and the sequence which may be followed in the survey of the ordinary small rapid sand filtration plant. In no one instance will a plant possess all the features noted, while in many cases it will be found desirable to obtain additional information.

Sanitary survey of a distribution system. Blue prints or drawings of the distribution system should be studied to determine the kind and size of pipe used, and the location of cross connections, check valves, dead ends and unused portions which might be factors in permitting the entrance of contamination into the water in the mains.

The frequency and extent of repairs which necessitate a decrease or shutting off of the pressure in the pipes should be ascertained. All check valves which separate one part of the system from another, or one system from another, should be inspected to determine their efficiency, and if they are so located that it is possible for them to admit contaminated water to the system. The means of protecting the water in reservoirs from contamination with surface water, by man or by animals should be noted. The proximity to the mains of sources of contamination, such as leaking sewer lines, leaching cesspools, pit privies or latrines should be determined, especially if there is danger that reduction of the pressure in the mains will permit contamination from such sources to enter pipes.

When the water in a distributing system is contaminated, samples should be taken as indicated at various points, such as before and after the water passes through a reservoir or a loop, with a view to limiting the search for the source of contamination to a part of the system only.

Survey of a slow sand filtration plant. The factors to be considered in the survey of a slow sand filtration plant are in most respects similar to those pertaining to a rapid sand installation. The efficiency of the reservoirs in the clarification of the water under all meteorological conditions should be determined by a study of past records and by tests for turbidity made at the time of the survey. The average rate of flow and period of detention should be considered.

The rate of filtration should be determined and the method and appliances used to control the rate should be inspected. The method of cleaning the filter should be observed for defects which would result in the passage of contaminated water.

Surveys of temporary water supplies. Temporary water supplies are most commonly utilized by troops in bivouac or in temporary camps. Surveys of temporary water supplies are, therefore, generally limited to investigation of the sources relative to quantity and quality and the efficiency of the purification measures.

If more than one source is available, a survey is usually made with a view to determining which is the best supply in the military situation concerned from the standpoint of contamination, quantity, accessibility, or, at times, for develop-

ment into a semi-permanent or permanent supply. This survey varies in scope from a routine inspection to an extensive study according to the circumstances and the military situation.

The purification measures employed, such as the water sterilizing bag, emergency chlorination, or the mobile water purification unit, are observed with a view to detecting errors of technique or faulty operation which would result in contaminated water being delivered to the troops. This investigation should also include, where indicated, the facilities used to transport the water, such as water carts, water cans or tank trucks, and the measures taken to prevent recontamination subsequent to purification.

The efficiency of the measures used to purify temporary water supplies can be determined definitely only by bacteriological analysis of the purified water. Where practicable, routine samples for bacteriological analysis should be taken at prescribed intervals from water sterilizing bags, from the water delivered at water points, from storage tanks, or from the water carts or tanks used to transport the water.

WATER RECONNAISSANCE

A source of water supply for moving troops, for troops in the theater of operations, or for forces engaged in occupational work must frequently be located by reconnaissance. Only in extreme cases where there is a marked shortage or an absence of water will the water supply be a governing factor in the movement of troops or in the conduct of military operations. Ordinarily, the military mission will not be influenced by the availability of a water supply, and the best source of water from the standpoint of quantity, accessibility, and purity in the area in which the troops are operating, or will operate, must be located by reconnaissance.

Responsibility for water reconnaissance. The Corps of Engineers is responsible for the procurement and purification of water for the major units and installations in the theater of operations and is, therefore, responsible for water reconnaissance where such action is necessary.

In situations where intestinal disease is, or may become epidemic or where the protection of the health of the troops renders it desirable, the Medical Department assists in the

conduct of, or makes water reconnaissance and submits recommendations concerning the procurement and purification of water supplies. In the case of small units and installations or minor forces operating independently, engineer personnel may not be available for this purpose and the responsibility for water reconnaissance will devolve upon the Medical Department personnel attached to such organizations.

Conduct of water reconnaissance. Information as to the location and extent of water supply sources in a given area may be obtained from geologic or topographic maps, from government reports, from the inhabitants, from aerial photographs or by reconnaissance on the ground.

The purpose of a water reconnaissance is to locate a suitable source of supply and determine, if indicated, the quantity of water available from a given source, the time and labor required to develop it, and the quality of the water, in so far as the quality will influence the purification measures. In scope, the reconnaissance may consist of inspection of an easily accessible and satisfactory supply, a more extensive survey to determine upon the best of two or more unsatisfactory sources or to locate one satisfactory supply, or a study of larger or smaller water works systems. The following summary indicates the points that should be covered in the average water reconnaissance. Not all the points given in the summary are applicable in any one situation, while in some instances it will be necessary to secure data not mentioned therein.

Summary of points to be covered and reported on in a water reconnaissance.

(a) *Location.* Sources and works should be shown on a map or the location given by description.

(b) *Character of sources.* Well, spring, stream, lake or pond.

(c) *Quantity of water available.*
   Rate of flow of streams.
   Rate of flow and capacity of wells.
   Rate of flow of spring.
   Dimensions and estimated depth of lake or pond and, if indicated, rate of inflow and outflow.

(d) *Quality of water.*
   Turbidity.
   Color.

Taste.

Result of bacteriological examination, if indicated, and if it is practicable to secure samples and have them analyzed.

(e) *Source of bacterial contamination.*

Character of sources.

Location in relation to water supply.

Control measures indicated.

(f) *Accessibility.* Accessibility of sources of water to troops by railroad, highway, improvised roads, trails, or hand carry.

(g) *Wells.*

Diameter.

Depth of well.

Depth of water.

Distance from surface of ground to the surface of the water.

Type, condition and depth of casing or lining.

Kind of soil.

Nature of impervious strata, if indicated and ascertainable.

Method of recovering water; i.e., pump, windlass, etc.

(h) *Spring.*

Kind of spring.

Protection provided; i. e., coping, water tight basin, ditching, etc.

(i) *Streams.*

Mean velocity.

Mean width.

Mean and maximum depth.

Nature of stream bed.

Height of banks above surface of water.

(j) *Existing installations.*

Purification facilities—chlorinating apparatus, filters, etc.

Pumps—number, type, size, speed and capacity.

Engines—type, size, speed and horse power.

Electrical equipment.

Storage facilities—type and capacity.

Pipe lines—length, size and material.
Present condition (description).

(k) *Proposed developments.*
Description.
Material available.
Material required.
Time required.

Maps and conventional signs for water supplies. Wherever practicable, the data obtained by water reconnaissance should be transferred to a map by the use of conventional signs. A map is one of the best means of recording certain parts of such information and transmitting it to others. The conventional signs depicted on page 374 may be used for this purpose.

Valves	
Air Valves	AV
Check Valves	
Tees (with size)	4×2×4
Wyes	
Elbows	
Laboratory	La
Mobile Purification Unit	M.P.U.
Pump	P.
Tank & Reservoirs (with numbers and capacity)	1/5000 3/1000
Water Point	
Water Point, animals only (number of animals)	U 20
Railway Water Point	R.W.P.
Railway Spill Tank	R.S.T.
Water Works	W W
Engineer Water Supply Battalion	W. S.
Well	
Spring	
Direction of dip	
Flowing well areas	Green
Pipe line or aqueduct (diameter may be shown)	4" Blue
Water Tank Train	W

CHAPTER VII.

SANITATION OF SWIMMING POOLS

A swimming pool is a body of water that is utilized for bathing and recreational purposes and is contained in a basin, tank or natural depression in which the flow of water is controlled by artificial means. The term swimming pool does not, therefore, include bathing beaches, ponds or streams.

Usually, a swimming pool is operated by the Quartermaster Corps, particularly in so far as the mechanical features relative to the operation of filters and chlorinators and the filling and draining of the pool are concerned. The recreation officer, or an officer designated by the commanding officer for such duty, is usually directly responsible for the control of the bathers and the pool attendants and for the immediate supervision of water purification procedures.

The Medical Department is responsible for the sanitary control of swimming pools. In scope, the sanitary control of a swimming pool includes the following:

a. Recommendations relative to construction of pools, in so far as the type of construction affects the health or safety of the bathers.

b. Inspections and recommendations pertaining to and technical supervision of all features of operation which would affect the health or safety of the bathers.

c. Laboratory analysis of the water.

TRANSMISSION OF DISEASE BY SWIMMING POOL WATER

Swimming pool water constitutes a medium by which certain pathogenic organisms may be transferred directly from bather

to bather and is always a potential agency of transmission for those pathogenic organisms that can survive in and be carried by water. Any bather may be a carrier of pathogenic organisms transmissible by swimming pool water or he may be susceptible to the disease produced by such organisms. A chain of infection is thus established in any group of bathers and the transmission of disease made possible. As neither the undetected carrier nor the susceptible individual can be excluded from a pool, the transmission cf disease by swimming pool water can be prevented only by the immediate elimination of all pathogenic organisms by purification of the water.

The infections transmitted by swimming pool water are due to organisms introduced into the water by the bathers in body secretions and discharges and from the skin surface. At *bathing beaches* where the large volume of water affords ample dilution, the contamination of the water is ordinarily caused only by sewage (page 605). Purification of bathing beach water contaminated with sewage can be best accomplished by diverting or by purifying the sewage.

The intestinal diseases, such as common diarrhea, the dysenteries and typhoid and paratyphoid fevers, may be transmitted by swimming pool water. The respiratory diseases, especially those which affect primarily the throat, nasal passages and sinuses, such as coryza, or diphtheria or scarlet fever may also be disseminated by swimming pool water. Swimming pool water may serve as a transmission agency for the causative agents of conjunctivitis, ear infections, and infection of the skin and subcutaneous tissues. Fungus infection of feet (*epidermophytosis*) is frequently transmitted by indirect contact in swimming pool bathhouses. Diving and swimming may cause traumatism of the tissues of the ear or sinuses with subsequent infection by preexisting organisms.

TYPE, SIZE AND CAPACITY

An army swimming pool is installed to provide recreational facilities for the military personnel and, in many instances, for the trainees of summer training camps. The duties and activities of these individuals are usually such that they can use the pool only at given hours, usually in the late afternoon and evening. The daily bathing period for an army pool is therefore

much shorter than that for the average civilian pool. The peak of the daily bathing load is usually reached within a short time after the beginning of the daily bathing period and the load remains high throughout the bathing period. This is particularly true if the pool is used by summer camp trainees. These factors should be considered in determining the type of pool to be installed at an army station or camp, its capacity and structural features, and operating procedures. As compared with a civilian pool, the army pool should be larger in relation to the size of the population to be served, more facilities for diving and water sports, such as racing or games, should be provided, and the purification procedures must be adequate to care for relatively larger peak loads.

As a rule, the army pool is an outdoor pool and in the United States it is, in most instances, operated only during the warmer months. An indoor pool differs generally from an outdoor pool, in so far as structural and operating features are concerned, only in that the water of an indoor pool is usually heated when necessary.

Size of pool in relation to strength of command. The size of the pool required for a station or camp is based on the maximum current bathing load, that is, on the number of bathers that may be expected to use the pool at any one time (page 403). The maximum number of bathers that a pool will accommodate at one time is governed by the surface area of the pool and is not, within limits, affected by the depth of the water or the capacity of the pool as expressed in gallons or cubic feet.

The strength of the command is the principal factor in estimating the number of bathers that will use a pool at any station or camp, but other factors must also be considered, such as climatic conditions, other recreational facilities, or the location of the pool. Under average conditions, the sizes given below are approximately the minimum:

Strength of command	*Maximum current bathing load*	*Surface area of pool*
500	55	1500 sq. ft.
1000	92	2500 sq. ft.
2000	133	3600 sq. ft.

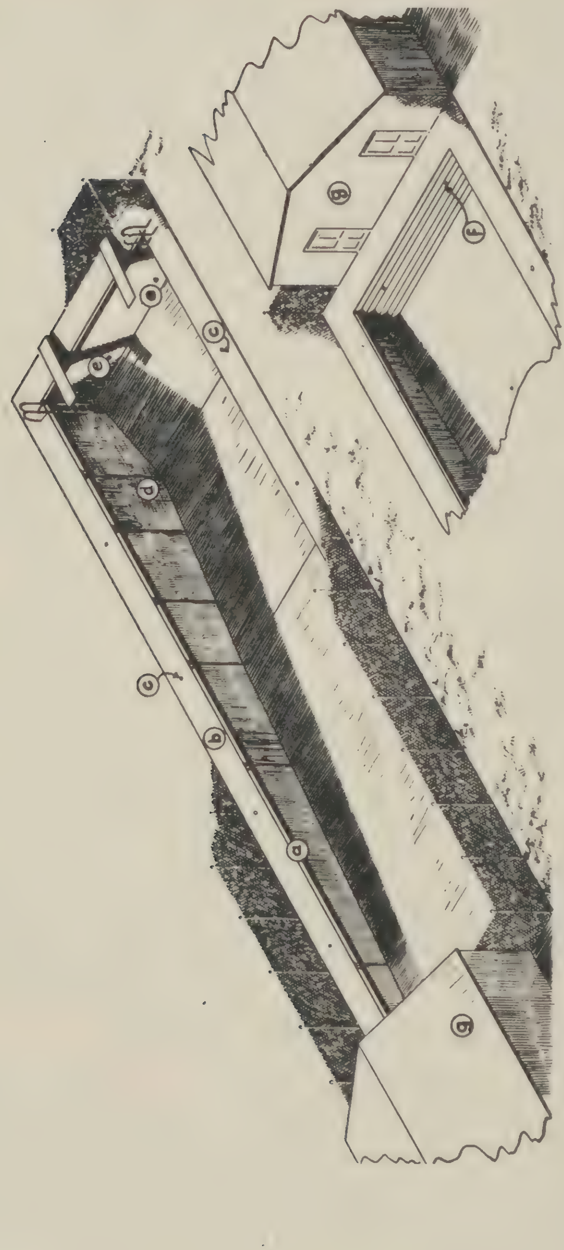


FIG. No. 98. Fill and draw swimming pool. a—Scum gutter. b—Runway. c—Runway drains. d—Pool outlet. e—Inlets at deep end of pool. f—Inlets at shallow end of pool. g—Bathhouse.

Artificial swimming pools at army stations or camps are usually rectangular, but may be elliptical, circular or irregular in shape. Regardless of the shape of the pool, the minimum surface area should be at least 1200 square feet. A pool which is to be used for water sports should be rectangular and have a minimum length of 60 feet and a minimum width of 20 feet. In the construction of larger pools, where other factors do not render it undesirable, the width should be a multiple of five feet as the racing lane is usually five feet in width.

Depth. The depth of the water at various parts of the pool is an important factor in the prevention of accidents. Not all persons who will use an army pool can swim and, in many instances, provision must also be made for the use of the pool by the children of army personnel. The pool should be so constructed that shallow water is provided for these non-swimmers. On the other hand, every pool should afford water of sufficient depth that divers will not be injured. In order to meet these requirements, a pool should have both shallow and deep areas.

Location of shallow and deep areas (Fig. No. 98). The rectangular pool is usually constructed so that one end contains shallow and the other deep water. In the larger rectangular pools, the deep water may be in the center with shallow water at both ends. In the case of irregularly shaped, elliptical or circular pools, the deep water may be in the center with an area of shallow water completely around the borders of the pool.

Variation in depth. The bottom of the ordinary rectangular pool should slope so that the water varies in depth from two to three feet at the shallow end to from seven to ten feet at the deep end. The bottom slope is not uniform throughout the length of the pool but is gradual in the shallower and more abrupt in the deeper portions (Fig. No. 98). The slope of the bottom from the shallow end to the six-foot depth should be not more than one foot in fifteen lineal feet. A bottom slope that is steeper than one in fifteen, where the depth will permit the bather to walk, may cause accidents due to slipping, or to non-swimmers or poor swimmers walking suddenly beyond a safe depth.

Beyond the six-foot depth, the bottom of the pool should slope directly to the deepest part at the deep end. Usually, the deepest part is at or slightly beyond the end of the diving boards.

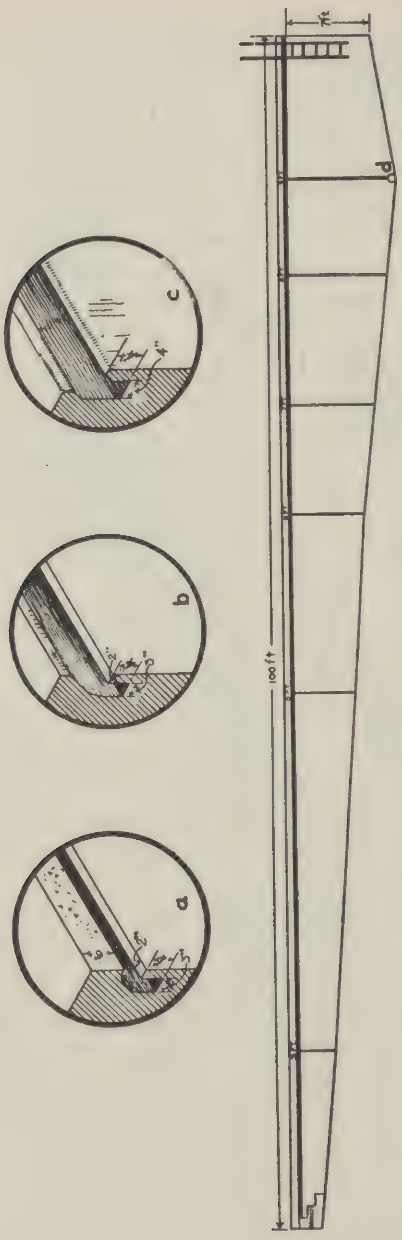


FIG. No. 99. Plan of side wall of a swimming pool showing slope of floor and depth. a, b, c—Different types of scum gutters. d—Outlet drain.

From this point to the end wall the bottom may slope upward in order to decrease the capacity of the pool and thus effect a saving of water.

Markings. In order that all bathers may know the depth of the water at any given point in the pool, figures showing the depth should be plainly painted on both sidewalls of the pool above the water line at the three and five foot depths, and thereafter in one foot increments as the water increases in depth towards the deep end. In large pools which have deep water only in the middle, the three and five foot depths should be marked on the bottom and indicated by floats. Racing lanes should be marked on the bottom with bands of dark colored cement from four to six inches in width and five feet apart from center to center.

Lining. The bottom and sides of the pool should be lined with light or white material. White cement, tile or glazed brick may be used for this purpose. A dark colored or blue lining does not show the deposited dirt and may be a menace to the bathers in that, by obscuring the bottom, it prevents them from properly estimating the depth of the water.

Capacity of swimming pools. The average swimming pool at a military station has a capacity of from 50,000 to 125,000 gallons. A pool 65 feet long, 20 feet wide and 3 feet deep at the shallow end, and 8 feet deep at the deep end, will hold approximately 50,000 gallons. A pool 100 feet long, 25 feet wide, 2 feet deep at the shallow end and 9 feet at the deep end has a capacity of approximately 100,000 gallons.

Scum gutters. The scum gutter is a recess in the walls of the pool at the surface level of the water. It serves to remove floating organic matter, such as debris or scum, which is carried into the scum gutter by wave action and overflow.

Construction of scum gutters (Fig. No. 99). In pools more than 25 feet wide and 100 feet long, the gutter should pass completely around the pool so that floating organic matter may be removed through the gutters in the end walls, as well as by those in the side walls. Side wall gutters alone will usually prove satisfactory for pools less than 25 feet wide and 100 feet long.

In order to be effective, the scum gutter must be constructed so that the wave action will not force material in the gutter back into the pool before it reaches the drains. As the scum gutter serves also as a hand-hold for swimmers, it must be deep enough

and so shaped that the fingers of the bathers will not reach and come in contact with organic matter deposited on the bottom of the gutter. As a rule, a scum gutter should be at least six inches deep and six inches wide.

In order to prevent injuries, such as abrasions and bruises, the edge of the gutter should be even with the inner surface of the wall. It may, however, be allowed to project into the pool for a distance of not more than two inches so that it will collect the overflow from the runway above.

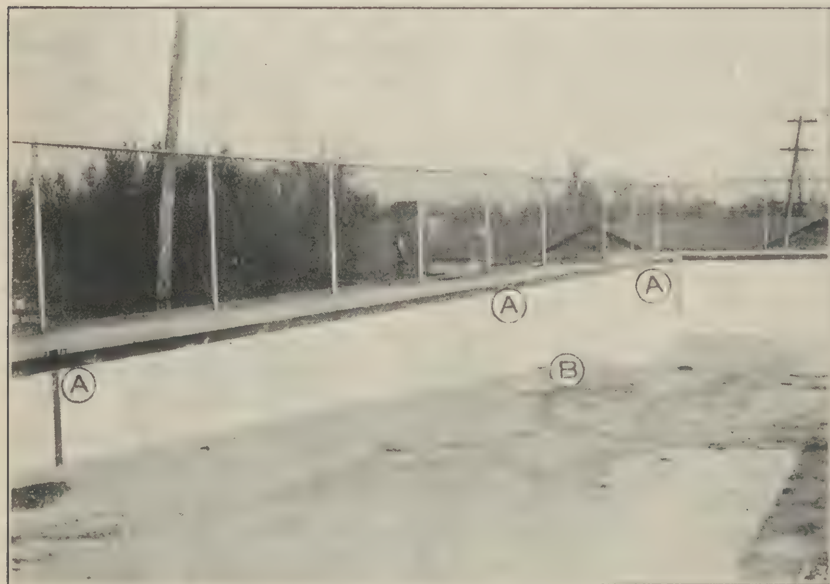


FIG. No. 100. Side wall and floor of a recently drained fill and draw swimming pool. A—Depth markers. B—Pipe for distribution of calcium hypochlorite solution. This pipe enters through the outlet drain.

Screened drains should open from the bottom of the gutter at intervals of ten feet and the bottom should slope slightly toward the drains. The water from the scum gutter may be discharged through the drains to a sewer, or to a filter for recirculation.

Inlets and outlets. The location and size of the inlets and outlets depend largely on the method of filling and draining the pool, that is, whether by the fill and draw method or

by recirculation (*continuous flow*), and also to some extent on the shape of the pool.

Where a pool is drained into a sewer, the connection between the outlet pipe and the sewer must be such that sewage cannot flow back into the pool. Where there is a possibility that sewage might flow back into the pool, the pool water may be drained into a manhole and then into the sewer. A check valve may be used, provided care is taken to prevent leakage.

Inlets and outlets for the fill and draw pool (Fig. No. 98). In the operation of a fill and draw pool which is provided with scum gutters, a small quantity of water is admitted from time to time during the bathing period to replace that lost by overflow through the gutters, and for this reason the best location for the inlet is in the wall of the deep end slightly below mid-depth. As the cooler inflowing water is admitted to the deep part of the pool it tends to displace the used water into the scum gutter.

The outlet of a fill and draw pool, through which the pool is drained, should be installed at the deepest part of the pool and lead into a drain pipe which will carry the water into a sewer or to some place of final disposal. It may be located in the floor of the pool or at the junction of a side wall and the floor (Fig. No. 98). It should be covered with a grating to exclude debris. The outlet and discharge pipe should be of sufficient size and have sufficient fall to empty the pool in not more than two hours.

Inlets and outlets for recirculation pools (*continuous flow*). In the recirculation pool, the water is pumped out of one part of the pool, filtered and chlorinated, or chlorinated without filtration, and readmitted into another part of the pool. To accomplish the best results by this method, the inlets and outlets should be so located in relation to each other that the formation of short circuiting currents is avoided and a maximum degree of dispersion of the clean water is attained.

The inlets for a rectangular pool should be located in the side and end walls and should be not more than twenty feet apart. Irregularly shaped pools should be studied to determine the best location for the inlets. In some instances, all or a part of the water may be admitted to a pool as a spray or cascade.

The outlet, or outlets, of a recirculation pool is usually located in the deepest part of the pool. Multiple outlets should be provided for pools which are more than twenty feet in width.

These outlets are usually located in the floor or in the end wall of the deep end and so spaced that they are not more than twenty feet apart nor more than ten feet from a side wall. A separate drain outlet may be installed through which the water can be drained into a sewer, or the drain or outlet pipe of the recirculation system may be connected with a sewer by a bypass.

Walls. The side walls and the deep end wall should be perpendicular. The shallow end wall of a rectangular pool may be constructed entirely or in part in the form of steps leading from the pool to the runway (*infra*).

The lining of the pool, including all walls and bottom, should be of smooth finished cement. All cracks and joints should be eliminated and the corners should be rounded.

Steps and ladders. The ordinary rectangular pool of average size should have broad steps leading from the bottom of the shallow end of the pool to the runway. The steps should, where practicable, extend across the entire width of the pool (Fig. No. 98).

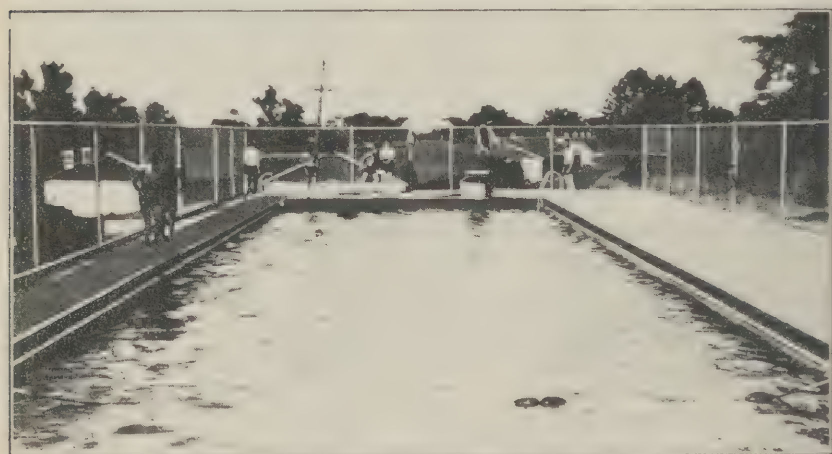


FIG. No. 101. Swimming pool 25 feet wide by 100 feet long, showing scum gutters and location of diving boards and ladders.

A ladder should be placed at each side of the pool on the side walls between the end of the diving boards and the end wall (Fig. No. 101). These ladders should extend down into the water to at least mid-depth in order to assist an exhausted swimmer to find the ladder steps with his feet. Ladders

should be equipped with hand rails on each side leading over the edge of the pool to the runway.

Recessed step holes in the walls of the pool may be used in lieu of ladders but are usually less satisfactory.

The treads of the ladders or step holes should be faced with some material that will prevent slipping.

Runways. A concrete runway at least four feet wide should be constructed entirely around the pool with the inner edge even with the upper edge of the pool walls. The runway should have a slope of one-quarter inch per foot towards drain openings placed at intervals of twenty feet in the center of the runway. The drain openings should be covered with a removable perforated or slotted plate, the upper surface of which is level with the surface of the runway. The drains may lead into a sewer or into the scum gutter drain.

The runway between the bathhouse and the pool is subject to the most traffic. It should be constructed with a marked slope away from the pool and this part of the runway should be especially well drained.

The edge of the pool wall where it joins the runway should be well rounded. The surface of the runway next to the pool should be roughened for a width of at least one foot to obviate slipping, or the runway may be partially covered with matting or similar material.

Pool enclosure. The outdoor pool should be enclosed in such a manner that the only entrance to the enclosure is through the bathrooms. The best material for enclosing an outdoor pool is heavy woven wire fencing from six to eight feet high, but a board wall or wooden fence may be used for this purpose.

Preferably, the fence or wall should be placed at the outer edge of the runway so that all the surface of the ground within the enclosure is covered with concrete. If sand beaches are used, all the area within the enclosure not covered by concrete should be covered with clean sand to a depth of at least one foot. Any part of the area not covered by concrete or sand should consist of firmly tamped earth and be kept free from loose dirt or grass. Uncovered areas of earth, or grass plots within the enclosure, will result in dirt being carried into the water with consequent interference with purification measures.

BATHHOUSES

The bathhouses should be so situated that entrance to the enclosure can be gained only through the shower bathroom. The bathhouse for an army pool should consist of one building containing dressing rooms, toilet facilities, shower bathrooms and an office room for the attendants and for the issue of bathing suits. An army pool is primarily for use by the troops, but at many stations provision is also made for women bathers. If this is done, a dressing room or dressing compartment, shower baths and toilet facilities must be provided for women. Usually, these are placed in the same building as the facilities for the troops but are completely separated therefrom by a partition.

Location of bathhouses. In the case of the rectangular outdoor pool, the best location for the bathhouse is at the shallow end of the pool where it forms a part or all of the end of the pool enclosure. As most of the bathers tend to congregate around the deep end of the pool, the location of the bathhouse at the shallow end tends to obviate crowding around the doors of the bathhouse.

Shower baths. The number of shower baths to be provided in relation to the number of bathers depends somewhat on the size of the pool. The average civilian pool is provided with one shower bath for every 40 bathers of the maximum load. A larger number is required for an army pool because the maximum load is, as a rule, more quickly attained and, under these circumstances, an inadequate number of showers either delays the entrance of the bathers into the pool or results in failure to cleanse the body properly before entering the pool. In the case of small pools having a maximum current bathing load of between 30 and 50, one shower head should be installed for every ten bathers of the maximum load. Shower heads should be provided for the larger pools on the basis of one for every fifteen bathers where the maximum current bathing load is between 50 and 100, and one for every twenty bathers where the load is more than 100.

Each shower should have a drain outlet. The floor of the bathroom should be made of impervious material and have a slope of one-quarter inch to the foot towards drainage

outlets. Provision must be made for heating the bath water and, usually, a small heating plant with a hot water boiler is installed adjacent to the bathhouse.

Toilets. The bathhouse should be provided with one toilet and one urinal for every twenty-five men, or fraction thereof, of the maximum current bathing load.

Dressing rooms. The bathhouse should contain one large dressing room for the men, which should be of sufficient size to accommodate twenty-five per cent of the maximum current bathing load at one time. Dressing compartments are not necessary. The floor of the dressing room should be made of impervious material. It should have a slope of about one-quarter inch to the foot towards a drain so that it can be washed with water from a hose. The walls of the dressing room and all furniture should likewise be made of materials which can be washed with water under pressure from a hose.

The dressing room should be provided with benches affording seating facilities for twenty-five per cent of the maximum current bathing load. A sufficient number of hooks should be provided to accommodate the clothing of all bathers. Lockers are desirable for this purpose but are not necessary.

Foot baths. The use of the foot bath is essential in controlling the transmission of fungi infections of the feet. All bathhouses should be equipped with foot baths so located that the bathers must use them when entering and leaving the shower baths. A foot bath may also be placed in the passageway between the dressing room and the pool. The foot bath container should be of concrete, or rubber lined, about six inches deep, and at least two feet, and preferably three or four feet, square.

A solution of calcium hypochlorite containing 0.5 per cent of available chlorine has been found to be effective and practical for use in the foot baths. This solution is made by adding one ounce of Grade A calcium hypochlorite (page 292) to one gallon of water. Solutions containing from ten to twenty per cent of sodium thiosulphate have been used for this purpose, but have not always given good results. The poor results occasionally obtained with sodium thiosulphate may be due to the use of a poor grade of the chemical or to the use of old solutions. Also, sodium thiosulphate is a dechlorinating agent (page 320) and if car-

ried into the pool on the feet of the bathers will serve to reduce the amount of available chlorine in the pool water.

Drinking water. A drinking fountain should be installed in each dressing room.

Operation and care of bathhouses. The organic matter which would otherwise be carried into the pool on the bodies of the bathers can be materially reduced in quantity by requiring that all bathers take a cleansing shower bath with warm water and soap before entering the pool enclosure. A preliminary warm shower bath should, therefore, be required of all bathers, not only as a disease control procedure, but also for aesthetic reasons. The shower bath should be taken with the body nude, the soap being completely removed from the body by rinsing in the shower bath.

All bathing suits and towels which are issued to troops should be sterilized after having been used by one man. The use of personally owned bathing suits, or towels, by persons other than the owner should not be permitted.

The floors and walls should be kept scrupulously clean at all times. The floors, benches, stools and toilet seats should be thoroughly scrubbed with a stiff brush at least once each day. A chlorine solution made by dissolving one ounce of Grade A calcium hypochlorite in two gallons of water should be used for this purpose. A two per cent solution of cresol may be used.

DIVING EQUIPMENT

The diving equipment for smaller pools usually consists only of diving boards, but diving towers and platforms may be found desirable for large pools. Defective or improperly installed diving boards, towers or platforms are always a potential cause of accidents. All diving equipment must be so constructed and anchored as to insure stability under the heaviest load or the greatest stress that will be placed upon it. The under water construction of diving towers, floats or platforms, such as braces, pillars or cables, should be such that bathers cannot be entangled, trapped or injured. Diving boards should have ample strength and be securely anchored to a concrete base.

Location of diving boards. A diving board or platform should be so located that it will be separated from any wall

by at least six feet and from any other diving board or platform by at least ten feet of clear space.

Elevation of diving boards or platforms. The maximum safe height of a diving board or platform above the water for the average diver is governed, within limits, by the depth of the water. However, no diving from a diving board should be permitted from a height greater than ten feet, nor from a diving platform at a height of more than twelve feet above the surface of the water, except by expert divers and then only under proper supervision.

The maximum safe elevation of a diving platform above a given depth of water is slightly more than that for a diving board because of the greater force with which a diver using a diving board strikes the water. The maximum elevation of diving boards and diving platforms above the surface of the water, in relation to various depths of water, is given in the following table:

Minimum depth of water (in feet)	*Maximum safe elevation above water (in feet)*	
	Diving Board	*Diving Platform*
6	1	3
7	3	5
8	5	7
9	7	9
10	10	12

PURIFICATION OF SWIMMING POOL WATER

The primary purpose of purifying swimming pool water is the elimination of pathogenic organisms. Purification procedures may also be designed to remove suspended matter, with the consequent clarification of the water.

Purification of swimming pool water is accomplished by chlorination alone or by chlorination combined with consecutive dilution. Purification by consecutive dilution may be accomplished by refiltration and recirculation or by a continuous flow of clean water into the pool.

From the standpoint of purification there are two types of swimming pools,—the continuous flow, and the fill and draw.

The continuous flow pool is one into which clean water is being constantly admitted simultaneously with the withdrawal of dirty water. The water may be continuously pumped from the pool through a filter and returned to the pool, or a continuous flow of clean water may be admitted to the pool, displacing a like quantity of used water which is discharged from the pool as waste water.

The difficulties encountered in purifying the water render the fill and draw swimming pool much less desirable and less efficient than either the recirculation or the flowing through pool. However, because of the comparatively low cost of installation and operation, and also because of local conditions, the fill and draw pool is used at a number of army stations and camps.

In the operation of a typical fill and draw pool, the pool is filled with water and this water is utilized for bathing purposes, except for the addition of relatively small quantities to replace that lost through the scum gutters, until the total bathing load is reached, when the pool is emptied, and cleaned and refilled (page 402). This procedure may be modified by the removal of a part of the water at definite intervals and refilling to the level of the scum gutters with clean water, or by the admission from time to time of a quantity of clean water which will dilute the used water in the pool, the excess being simultaneously discharged either through the scum gutters or an outlet.

A continuous flow pool has the advantage that the water is relatively clear and attractive at all times. However, the water in a fill and draw pool can be kept purified by continuous chlorination, and when a fill and draw pool is properly operated it is as satisfactory from a health viewpoint as a well operated continuous flow pool.

Recirculation system. A recirculation system consists of a pump and pipes connecting the pump with the outlet and the inlet of the pool, together with filters, chlorinator and ammoniator, and other appurtenances that may be used for the purification of swimming pool water. Usually, a recirculation system is operated in connection with refiltration, but the water may be passed through a recirculation system without filtration for the purpose of facilitating chlorination, providing a means of straining out debris, or operating a suction cleaner.

The pump or pumps, the recirculation pipes, the chlorinator and ammoniator, and the filter should be located outside the pool enclosure. In outdoor pools, the pump, chlorinator and ammoniator, and filter may be located in a building designed for that purpose or in a room in the bathhouse.

Pumps. A centrifugal pump operated by an electrically driven motor should be used. Duplicate pumps may be installed for the larger pools.

Piping. Ample pipe capacity should be provided and loss of head due to frictional resistance reduced to a minimum. The piping should be so installed that any part of it can be quickly taken down and repaired. Taps should be provided through which samples of water may be obtained for analysis before and after chlorination or filtration.

The pipe line for supplying fresh water to the pool should be separate from the circulation system. In any event, there should be no cross connection between that part of the circulation system which is under pressure and a domestic water supply. If the pool supply line is connected with the circulation system of the pool, it should be connected on the suction side of the pump and the cross connection protected by an adequate check valve.

The recirculation system should contain a strainer for the purpose of catching and retaining hair and suspended debris. This strainer usually consists of a closed cylinder of noncorrosive metal with holes or slots about 1/32 inch in diameter and is so installed that the water passes through it from the outside. It should be placed so that it can be easily removed for cleaning.

Chlorination of swimming pool water (page 289). Each bather as he enters the water introduces additional increments of organic matter, including organisms some of which may be pathogenic. In order to prevent the transmission of such organisms to others, the water must contain a disinfectant which will come into contact with and kill the organisms as soon as they are introduced into the water. Chlorine is the most satisfactory disinfecting agent which can be employed under the conditions surrounding the operation of a swimming pool.

The chlorine demand of swimming pool water, or the quantity of chlorine required to combine with all the organic matter present and kill all the bacteria, varies with the quan-

tity of organic matter (page 290). When bathers enter the pool, they carry organic matter into the water on their bodies and bathing suits. This organic matter absorbs the excess chlorine, which is also absorbed by the bathing suits and disseminated into the air by agitation of the water. As the quantity of organic matter in the water increases constantly while the pool is in use, there is a constantly increasing chlorine demand. In order to satisfy this chlorine demand, and effect continuous disinfection of the water, residual chlorine must be present in the water at all times during a bathing period in quantities sufficient to satisfy immediately the chlorine demand of new increments of organic matter.

During recent years experience has shown that the treatment of swimming pool water by means of the ammonia-chlorine process (page 305) is generally more satisfactory than treatment with chlorine alone. A greater content of residual chlorine in the form of chloramines can be maintained without causing irritation of the conjunctiva and the nasopharyngeal membranes or producing disagreeable tastes and odors. Where the ammonia-chlorine process is employed, the range between the effective minimum quantity of residual chlorine and the permissible maximum amount is much wider than when chlorine alone is used. Consequently, the ammonia-chlorine process permits of greater flexibility in the operation of the pool, and affords a higher degree of protection against contamination, than does chlorination alone.

As a rule, from 0.2 to 0.5 parts per million of residual chlorine (page 290) are required to insure continuous disinfection of swimming pool water. While 0.1 part per million is sufficient to disinfect clear water, it will not provide for continuous disinfection if the quantity of organic matter is rapidly increased. Where chlorine alone is used, a concentration of residual chlorine of more than 0.5 parts per million will produce irritation of the conjunctiva and the nasopharyngeal membranes in susceptible individuals. Under these conditions the chlorine should be applied in such quantities and in such a manner as to maintain a residual chlorine content of from 0.2 to 0.3 parts per million, with permissible temporary minimum and maximum limits of 0.2 and 0.5 parts per million respectively. Where the ammonia-chlorine treatment is employed, the minimum residual chlorine content should

be 0.5 parts per million and the maximum 1.0 part per million. The most desirable range is from a minimum of 0.7 parts to a maximum of 1.0 part per million.

In the treatment of swimming pool water by means of the ammonia-chlorine process, the ratio of ammonia to chlorine varies from one to three to one to ten. Care must be taken to prevent the accumulation of free ammonia in the water and the water should be tested at frequent intervals for free ammonia.

Either liquid chlorine or calcium hypochlorite may be employed in the chlorination of swimming pool water (page 292).

Liquid chlorine is commonly employed in the purification of the water in continuous flow pools. As a rule, calcium hypochlorite is used in the treatment of the water in the fill and draw pools, although liquid chlorine may be utilized instead. Because of the difficulties encountered in applying small quantities of chlorinated lime, only Grade A calcium hypochlorite should be used in the treatment of swimming pool water.

The apparatus used to apply solutions of chlorine or ammonia to swimming pool water is the same in principle as that employed in the purification of drinking water (page 293) (Figures No. 61 to 76).

The operation of a chlorinator for the application of liquid chlorine in solution requires that water under a pressure of at least fifteen pounds be available. This supply may be piped from a pressure main or from the recirculation system.

The calcium hypochlorite solution is prepared in a solution tank from which it is piped to the water at the point of application. The solution tank should consist, preferably, of a concrete receptacle, but a wooden barrel or tank may be used (page 294). A 50-gallon tank should be provided for a pool having a capacity of 100,000 gallons or less. It is desirable that solution tanks be installed in duplicate so that, if necessary, a solution may be prepared in one while the other is in use.

The apparatus for preparing and applying chlorine and ammonia should be installed outside the pool enclosure and in such a manner that odors of chlorine or ammonia will not be perceptible to those within the pool enclosure or bath-

house. If a refiltration system is employed, the chlorinator and ammoniator should be placed in the filter house. In other types of pools, this equipment may be installed in a separate building constructed for that purpose or in a tight room adjacent to, or forming a part of, the bathhouse. If liquid chlorine is used, the room or building in which the chlorinator or the tanks are placed should be vented to the outside. The chlorinator and the ammoniator, and the tanks of chlorine and ammonia, should be so located that any person in the room can easily reach an exit in case of an accident resulting in the escape of gas.

Where the water is recirculated, the chlorine solution is usually applied in the suction pipe of the pump, but may be added to the water in the discharge pipe. The application of the chlorine solution to the water in the discharge pipe has the disadvantage that an injector must be installed to provide the required pressure, while the solution can be discharged into the water in the suction line by gravity alone. However, if the water is pumped to a filter, the latter method will require more chlorine in order to compensate for that absorbed by the excess organic matter in the water.

In pools which are operated by a continuous inflow and outflow of water, the chlorine is added to the inflowing water in quantities which will produce the desired amount of residual chlorine in the water in the pool.

In the chlorination of the water in fill and draw pools, the chlorine solution is conveyed from the chlorinator by a pipe which passes through the side or end wall, usually at or near the deep end (Fig. No. 100).

The ammonia may be applied as the anhydrous gas or as a solution of ammonium sulphate (page 310). In the operation of continuous flow pools, the ammonia should be added to the water before the chlorine is applied. Where the pool is of the fill and draw type, the ammonia may be applied before, with or after the chlorine.

A solution of calcium hypochlorite may be poured from buckets or other containers directly into the water of the pool. This is an unsatisfactory method and should not be used except in an emergency.

Dispersion of chlorine. In order for chlorine to serve as an efficient disinfectant, it must be thoroughly mixed with the water

so that it comes in contact with all particles of organic matter. In the continuous flow pools, the dispersion of the chlorine is accomplished by currents as the water flows through the pool. In some instances, recirculation without filtration may be utilized for the sole purpose of facilitating dispersion of the chlorine.

Various methods are employed to mix the chlorine and the water in fill and draw pools. The chlorine is usually applied to the water in the deep end of the pool where the diving and swimming activities of the bathers will serve to agitate the water sufficiently to diffuse the chlorine to all parts of the pool. Partial dispersion and mixing may be obtained at the moment of application by admitting the chlorine solution through a perforated pipe or hose line laid along the bottom or side of the pool, or by the use of multiple inlets placed in different parts of the pool.

The chlorine must be so diffused throughout the water that a sample of the water taken from any part of the pool will show a residual chlorine content of from 0.2 to 0.5 parts per million, if chlorine alone is used, or 0.7 to 1.0 parts per million where the chlorine is present in the form of chloramines. It is not practicable, however, to maintain the residual chlorine content at an equal and constant level throughout the pool, but it must be present in all parts of the pool at all times in quantities between the minimum and maximum limits.

Control of the chlorine content. The residual chlorine present in the water at any given moment during the bathing period is eliminated by absorption or aeration within a comparatively short time. Therefore, in order to maintain a concentration of residual chlorine which will destroy the organisms as they are introduced into the water, chlorine must be added to the water continuously or at short intervals, during the entire bathing period.

Prior to the beginning of the daily bathing period, sufficient chlorine solution should be added to the water to produce an average residual chlorine content of approximately 0.3 parts per million of chlorine alone, or about 0.8 parts per million if the ammonia-chlorine process is used. Thereafter chlorine is added to the water in quantities sufficient to maintain the residual chlorine content within the prescribed limits. As the amount of organic matter being introduced into the water increases and de-

creases, as indicated by tests for residual chlorine, the volume of the chlorine solution flowing into the pool is changed accordingly.

Tests for residual chlorine. Routine orthotolidine tests for residual chlorine should be made at intervals of approximately 30 minutes during the bathing period, using the technique described on page 313. In testing the water in the larger pools, two or more samples should be taken from different parts of the pool. In the case of the smaller pools, or pools in which the chlorine is well diffused, one sample from about the middle of the pool is usually sufficient. All samples should be taken from the surface of the water.

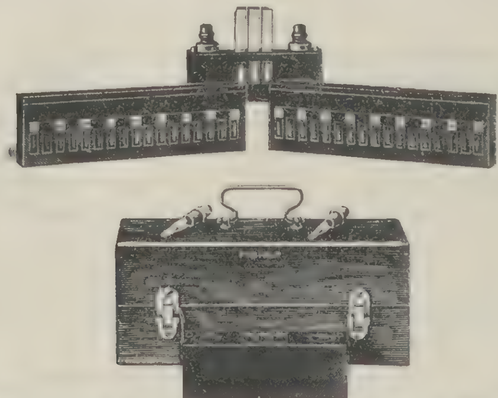


FIG. No. 102. Swimming pool test set for determining the pH and chlorine content of swimming pool water. (Courtesy of the Fisher Scientific Co., Pittsburgh, Pa.).

In making the orthotolidine tests, care must be taken to avoid false reactions due to interference by substances other than chlorine (page 315). Frequent bacteriological analyses should be made as a check on the efficiency of chlorination (page 358).

Filtration. Swimming pool water is filtered for the purpose of maintaining a clear and attractive water in the pool and facilitating subsequent disinfection by the removal of the organic matter. As contamination is being continuously introduced into the water in the pool, disinfection, rather than filtration, must be depended upon to destroy the pathogenic organisms. A pressure filter is ordinarily used, the water being pumped directly from the pool outlets through the filter

and back to the pool inlets. A gravity sand filter may be employed in the operation of large outdoor pools. When a pressure filter is employed in the treatment of swimming pool water, it is constructed and operated in the same manner as when used to purify drinking water (page 288).

Two or more filter units should be installed for the larger pools or where conditions render constant refiltration necessary.

Pressure filters are usually designed to operate at an average rate of not more than three gallons per square foot of filter surface per minute. At this rate, approximately 56 square feet of filter surface, or, stated in another way, a round filter unit eight and one-half feet in diameter, would be required to filter 100,000 gallons of water in ten hours of constant operation.

Coagulation. In order to obtain a clear and attractive effluent from a pressure filter, the water to be filtered must be coagulated (page 243). In the filtration of swimming pool water, alum is used as a coagulant and is usually applied as a solution to the water in the suction pipe of the pump, either by means of an alum feed pot or by chemical solution feeders (page 267). Solution feeders should be used where the pool has a capacity of 100, 000 gallons or more. If a feed pot is employed, the crystal or lump alum should be used, as the ordinary filter alum is too soluble.

Wherever practicable, the water should be passed through a coagulation basin affording a detention period of from twenty minutes to one hour (page 246). Ordinarily, the water flows from the pool to the coagulating basin by gravity and is then pumped to the filter.

Refiltration reduces, and will eventually entirely eliminate, the alkalinity of the water, necessitating the addition of sodium carbonate (soda ash) to maintain the alkalinity required for coagulation with alum and to prevent corrosion (page 246). Acid water is irritating to the membranes of the eyes, nose and throat of the bather. Also, it is more difficult to maintain the proper quantity of residual chlorine in acid water. Usually, the sodium carbonate solution is applied to the water in the suction pipe by means of a solution feeder, but an alum feed pot can be used. The solution may be poured directly into the water in the pool or in the coagulation basin. It is applied at the rate of about 0.5

grain for each grain of alum used. Not less than ten parts per million of alkalinity, or a pH reaction between 7.0 and 7.6, should be maintained at all times.

The alkalinity of the water can be roughly adjusted by placing several blocks of fused soda ash in different parts of the pool. The fused soda ash slowly dissolves and by varying the number of blocks the alkalinity of the water can be maintained within the desired limits.

The alkalinity may be determined by the usual technique as given in the Standard Methods of Water Analysis, using either phenolphthalein, methyl orange or erythrosine as an indicator. However, the test to determine the hydrogen ion concentration is simpler and is preferable in the treatment of swimming pool water.

Operation of filter. The filter must be washed when the loss of head is such that the rate of filtration is reduced, or the filtering efficiency decreased so that the water is no longer properly clarified (page 258). Usually, however, a filter is washed routinely at predetermined time intervals, such as, for example, every twenty-four hours, depending on the rate of filtration and the character of the water. Routine daily washing at a given hour is the most satisfactory method. If the filter is not operated continuously through the twenty-four hour period, it should be washed at the end of the daily run so as to prevent drying and hardening of the organic material on the surface of the sand. After the filter is washed, the water should be filtered to waste until clear, but this operation may be dispensed with if water saving is an important factor in the operation of the pool.

Rate of turnover. The effectiveness of refiltration and recirculation of the filtered water in maintaining clear water in the pool will be determined, within limits, by the proportion of filtered water that is mixed with the dirty water in the pool, in accordance with the law of purification by consecutive dilutions. For example, if the filter is started when the pool contains dirty water, the first portion of water pumped from the pool will consist entirely of dirty water, but as the filtered water re-enters the pool and if no more foreign material is added to the water in the meantime, the water withdrawn thereafter will consist of a decreasing proportion of dirty water and an increasing proportion of clean water. One turnover, that is, the passage through the filter and recirculation of a quantity of water equal

to that contained in the pool, will remove about 63 per cent of the suspended matter that was in the water prior to filtration; two turnovers will remove about 86 per cent; three will remove about 95 per cent; and five will remove approximately 99.3 per cent. After ten complete turnovers the water will be 99.99 per cent clarified.

The additional suspended matter which is introduced into the water by the bathers is likewise removed in accordance with the law of consecutive dilutions. Beginning with a clear water there is a gradual accumulation of suspended matter in the water until a certain quantity, called the balanced load, is reached which will vary only with the current bathing load, and the rate and efficiency of filtration. Thus, if a pool is operated at the rate of one turnover per bathing day, and assuming that the filter is 100 per cent efficient, an approximately constant quantity of suspended matter equal to about 58 per cent of the quantity introduced daily by the bathers, will be obtained in nine days. Two turnovers per bathing day will produce in four days a balanced load of organic matter equal to about 16 per cent of the daily increment; a balanced load of about three per cent will be reached in three days by three turnovers per bathing day; and a balanced load of about two percent in two days by four turnovers per bathing day.

The desirable turnover rate for a given pool is determined by the average daily bathing load and the efficiency of the filter. Under the usual conditions, one to three turnovers during each bathing day is sufficient. The number of hours of filtration required to accomplish one turnover depends on the capacity of the filter and the rate of filtration. For example, in the case of a 100,000 gallon pool, 56 square feet of filter surface are required to obtain one turnover in ten hours, with a filtration rate of three gallons per square foot of filter surface per minute.

Ultra-violet rays. Clear water can be sterilized by the application of ultra-violet rays. Ultra-violet ray lamps are so installed that the rays pass through a thin film of water as it flows past the lamps. In order to obtain the clear water necessary for ultra-violet ray sterilization, swimming pool water must be continuously refiltered, usually at a rate of not less than one complete turnover every four hours during the bathing period, and the bathing load must be fairly uniform. Water which has been sterilized with ultra-violet rays does not,

however, contain any residual disinfectant which would serve to destroy organisms as they are introduced into the pool waters by the bathers. There is no test, such as the orthotolidine test for residual chlorine, by which the efficiency of sterilization with ultra-violet rays can be immediately determined. Because of these disadvantages, the ultra-violet ray method of water sterilization is not as satisfactory as chlorination in the operation of army swimming pools.

Ionized silver. (*Katadyn silver*). Ionized silver has been employed to some extent in other countries to disinfect swimming pool water, but its use for this purpose in the United States has been largely experimental. The process of purification with katadyn silver depends upon oligodynamic action. The silver is deposited on the surface of certain substances, such as sand, porcelain, or the walls of the pool, and the water comes into contact with the silvered surfaces. Katadyn silver is bactericidal and it is claimed that the water treated by this method becomes bactericidal. However, the action of the silver is subject to interference by temperature, turbidity, certain minerals and organic matter. Disinfection is slow and treatment with ionized silver costs considerably more than chlorination. This process has not, as yet, been developed sufficiently to be of practical value in the treatment of swimming pool water.

Elimination of algae. Usually, the chlorine in the water serves to prevent the growth of algae in swimming pool water, but some species will grow in the presence of chlorine. Should algae become troublesome, they can be destroyed by dissolving copper sulphate in the water in the proportion of from 0.5 to 5.0 parts per million, or the pool may be drained and the walls and bottom scrubbed with a five parts per million copper sulphate solution. Sunning the empty pool for one day will usually kill the algae on the walls and bottom.

Bacteriological examinations. The principal purpose of purifying a swimming pool is to prevent the transmission of pathogenic organisms, and the efficiency in this respect of any methods or procedures employed can be definitely and finally determined only by bacteriological examination of the water. Standards of bacteriological purity with regard to the content of coliform organisms should be the same as for drinking water (page 358). The total bacteria count should not exceed 200 or-

ganisms per c.c. in more than ten per cent of the samples taken during any selected period, as determined by counts made from plates that have been incubated at 37°C. for 24 hours. Properly chlorinated water is, as a rule, free from coliform organisms and the orthotolidine test for residual chlorine is a measure of the efficiency of chlorination. Nevertheless, routine bacteriological examinations of the water should be made at regular intervals of from one day to a week as a check on all purification procedures.

Because of the relatively high residual chlorine content of swimming pool water it is desirable that the sample taken for bacterial analysis be dechlorinated immediately, in order that the chlorine will not kill the organisms before the sample can be cultured. The sample bottles should be prepared in accordance with the procedures recommended in the *Standard Methods of Water Analysis*, Eighth Edition, 1936, American Public Health Association, as follows:-

> *a. Moist heat sterilization (Option 1).* The sodium thiosulfate solution is prepared by dissolving 1.5 g. of sodium thiosulfate in 100 ml. of distilled water. One-half ml. of this solution is placed in each clean bottle. (This amount has been found sufficient to completely reduce residual chlorine in an amount up to 2 parts per million in a sample of 130 ml. of water). After the introduction of the sodium thiosulfate solution, the bottle is stoppered and capped with paper and rubber band. The bottles are then placed in an autoclave and sterilized for 15 minutes at 20 pounds pressure.

> *b. Moist heat sterilization (Option 2).* Into clean wet bottles add approximately 0.02 to 0.05 g. of powdered sodium thiosulfate. The amount need not be weighed. An estimated amount on the tip of a spatula is sufficiently accurate. The bottles are sterilized as in paragraph *a.* above.

> *c. Dry heat sterilization.* Into clean dry bottles is added from 0.02 to 0.05 g. of powdered sodium thiosulfate as in paragraph *b.* The bottles are stoppered, capped with paper and sterilized at 180°C. for 10 minutes. The temperature of sterilization must not exceed 220°C. as sodium thiosulfate decomposes at this temperature.

The sample should be collected by gently immersing the open bottle in the water and moving it slowly forward until filled. If the bottle is rinsed or moved rapidly through the water a part or even all of the sodium thiosulphate will be washed out of the bottle.

BATHING LOADS

Practically all organic matter which gains entrance into the water in a swimming pool is carried into it by the bathers. As the average amount carried into the water by each bather under constant conditions is approximately the same, the number of bathers that have used the water is a measure of the quantity of organic matter contained in the water at any given time, and is expressed as the bathing load.

The quantity of organic matter in the water determines the rate of chlorine absorption and, to a considerable extent, the amount of chlorine necessary to purify the water. An excessive quantity of organic matter renders it difficult to maintain the residual chlorine concentration within the desired limits and tends to produce disagreeable tastes and odors in the water, due to compounds formed by organic matter and chlorine.

The total bathing load. The total bathing load for a fill and draw pool is the maximum number of bathers that can use the water before enough organic matter is introduced to interfere seriously with chlorination or to render the water otherwise unsuitable for bathing. The total bathing load is computed on the basis of fifty gallons of clean water for each bather using the pool, where all bathers are required to take a preliminary shower bath. Thus, the total bathing load for each 1000 gallons of clean water is twenty bathers, or 2000 bathers for each 100,000 gallons.

In the case of the fill and draw pool, continuous chlorination will usually permit the water to be used without detriment to the health of the bathers until the total bathing load is attained. However, as the total bathing load is approached, considerable difficulty may be experienced in maintaining the desired concentration of residual chlorine, and disagreeable tastes and odors may occur. For this reason, it will, in many instances, be found desirable to reduce, arbitrarily, the total

bathing load for a fill and draw pool by as much as 50 per cent and allow a minimum of 100 gallons of clean water for each bather.

If the pool water is filtered at a rate of more than 50 gallons for each bather, a total bathing load, as defined above, would never be attained. Under these conditions, organic matter does not accumulate in quantities sufficient to impair the efficiency of chlorination, and thus render the water unfit for bathing purposes from the viewpoint of disease transmission. The number of gallons of refiltered water to be allowed for each bather depends on the degree of clarity which it is desired to maintain in the water in the pool. Given a well operated filter and conditions which do not permit the introduction into the pool of an immoderate quantity of organic matter, an acceptable degree of clarity can be maintained where the bathing load consists of one bather for each 300 gallons of filtered water admitted to the pool. Stated in other terms, the maximum bathing load for a pool having a capacity of 100,000 gallons and a filtration rate of one turnover per day should be about 330 bathers per day.

The current bathing load. The current bathing load is the number of bathers that can use the pool at any one time. It indicates the amount of organic matter that is being introduced, or the flow of organic matter, into the water while the pool is in use. The maximum current bathing load also represents the number of bathers that the pool will accommodate from the viewpoint of available space for swimming.

The maximum current bathing load is determined by the surface area of the pool. The space required for a swimmer is considered to be five-fourths of the square of his height which, for the average individual, is 36 square feet. However, as not all of the bathers will be in the water at the same time, an average of 27 square feet of water surface area is allowed for each bather within the pool enclosure. For example, a pool 25 feet wide and 100 feet long has a surface area of 2500 square feet and will accommodate 92 bathers within the pool enclosure at one time.

As the number of bathers in a pool increases toward the maximum current bathing load, the quantity of organic matter passing into the pool is increased and it becomes more and more difficult to maintain the residual chlorine concentration

within the desired limits. In the operation of many pools, it will be found practicable and advisable to reduce the permissible maximum current bathing load, as determined by the surface area of the pool, by from ten to twenty-five per cent.

EXCLUSION AND REMOVAL OF ORGANIC MATTER

A high organic matter content, or the rapid introduction into the water of organic substances, tends to interfere with chlorination procedures and to increase the load on the filters. Consequently, measures designed to prevent the introduction of organic matter into swimming pools or to reduce the organic matter content of the water are important and essential features of any purification process.

Suction cleaner. A suction or vacuum cleaner is a device to remove sediment from the bottom and walls by suction action without draining the pool. It consists of a hose, a suction nozzle and cleaning brush. In cleaning small pools, the cleaner is manipulated by means of a long handle. In large pools, the cleaner can be pulled along the bottom with ropes, or is operated by a diver using a diving mask. The hose is attached to the suction pipe of the pump. The water and sediment removed may be pumped to the filter or bypassed to a sewer.

Cleaning. All fill and draw pools should be cleaned when the total bathing load has been attained. However, even though the total bathing load has not been reached, the water in a swimming pool should be regarded as unsuitable for bathing purposes when dirt has accumulated on the bottom in such quantity that it is visible from above the surface of the water. In some instances, it may be desirable, for administrative reasons, to drain and clean the pool at predetermined intervals prior to the time when the total bathing load would be attained. For example, a pool may be drained and cleaned, as a routine operation, every three days, regardless of minor variations in the bathing load.

If the water is refiltered, it is seldom necessary to clean the pool except for aesthetic reasons. Usually, additional water is admitted from time to time to replace that lost through the scum gutters or in washing the filters and the pool is drained and cleaned about once a month. Otherwise, the

pool is cleaned only when sufficient dirt accumulates on the bottom and walls to render the water turbid or to interfere with chlorination.

A means of estimating the turbidity of the water can be provided by painting on the bottom in the deepest part of the pool, a black disc six inches in diameter on a white disc twenty-four inches in diameter. The clearness with which the disc can be seen is a rough measure of the turbidity of the water, and the pool should be drained and cleaned when the disc becomes invisible at a distance of thirty feet from a point on the surface of the water directly above the disc.

After a pool is drained the sediment on the bottom and on the walls should be removed by scrubbing with stiff brooms or with water under pressure from a hose.

EXCLUSION OF CASES AND CARRIERS OF INFECTIOUS DISEASE

It is impossible to exclude from swimming pools all cases of infectious disease, or any considerable proportion of the carriers of such disease. The surgeon of the command should furnish the officer in charge of the swimming pool with the names of all persons who might desire to use the pool and who are known to have an infectious disease, or who are known to be or are suspected of being carriers of infection. Obviously, these are individuals who are not sick enough to be confined to hospital or quarters. They include especially those having coryza, infections of the nose, throat or sinuses, ear infections, conjunctivitis, diarrhea, skin diseases, or open lesions of the skin or subcutaneous tissues due to infection, and those who have been in contact with cases of meningococcic meningitis, scarlet fever, measles or diphtheria. The surgeon should order such of these persons who are under military control not to enter the pool and all should be denied entrance to the pool by the pool attendants.

Where fungi infections are reported as occurring among those using a swimming pool, all bathers should be carefully inspected and no one showing evidence of skin infection, particularly on the skin of the feet, should be allowed to remain in the bathhouses or the pool enclosure. The floors, stools, benches, mats, runways, and the steps of ladders or

stairways above the surface of the water in the pool, should be scrubbed daily with a strong solution of calcium hypochlorite or other disinfectants.

The pool attendants cannot be expected to diagnose disease, but they should be instructed in the detection of external indications of certain of the more common conditions. They should be directed to forbid any person to enter the pool enclosure who presents evidence of a cold, discharge from the ears, inflamed eyes, skin disease, ulcers or sores on the surface of the body, or who is obviously ill. Any person who is wearing a bandage of any kind should be excluded, unless he can demonstrate that the bandage does not conceal an infectious lesion.

SWIMMING POOL ATTENDANTS

The attendants, who are usually enlisted men but may be civilian employees, must possess certain qualifications and be trained in the performance of their special duties. There should be at least two attendants on duty so that one may be actually within the pool enclosure at all times to perform life guard duties.

Duties of attendants. The general duties of swimming pool attendants include supervision of purification measures, the control of the admittance of bathers to the bathhouse and pool enclosure, the supervision of the bathers, including life guard functions, and the enforcement of all rules and regulations relative to the operation of the pool and the conduct of the bathers.

Training and qualifications of attendants. Swimming pool attendants must be reliable and thoroughly trustworthy individuals, as the health and sometimes the lives of the bathers will depend on their efficiency. Ordinarily, every pool attendant should be trained and qualified to perform the duties of a life guard and be able to rescue any bather from any part of the pool. In some instances, as in the case of the larger pools, selected men are trained in and assigned exclusively to life guard duties, while others are detailed for other duties in connection with the operation of the pool.

Selected attendants must be trained to operate the chlorinator and to make the orthotolidine tests for residual chlorine

and, if the water is refiltered, to operate the filter and pumps. The pool attendants should possess sufficient tact and force to enable them to supervise the bathers and to enforce the regulations without undue friction.

REGULATIONS FOR THE OPERATION OF SWIMMING POOLS

Regulations pertaining to the operation of a swimming pool and the conduct of the bathers should be published by competent authority. The following regulations are suggested, but not all of them will apply in the operation of a given pool and, in many instances, other rules must be promulgated to meet local conditions.

Regulations for bathers. The regulations for bathers should be printed on a placard and posted in a prominent place in the bathhouse or pool enclosure where they will be seen by all bathers.

The following regulations for bathers are typical of those used in the operation of the ordinary army swimming pool:

a. The orders, instructions, or requests of the pool attendants will be complied with by all bathers.

b. Not more than .... bathers will be allowed within the pool enclosure at one time.

c. All bathers will take a shower bath with warm water and soap before entering the pool enclosure. Bathing suits will not be worn in the shower bath. The soap will be rinsed off with warm water and the bathing suit put on without drying the body. Each bather will place both feet in a foot bath before entering and when leaving the shower bath.

d. All bathers visiting the toilets will take a warm water and soap shower bath in the same manner as directed in par. *c.* before re-entering the pool.

e. Expectoration, blowing the nose or spouting of water from the mouth into the pool is forbidden.

f. No articles of food will be carried into the bathhouse or the pool enclosure.

g. Smoking within the pool enclosure or shower bathroom is forbidden.

h. No person who has a cold or sores, ulcers or other skin diseases, discharges from the ears, or is wearing a bandage of any kind, or is otherwise sick will be permitted to enter the pool enclosure.

i. No person reported by the surgeon as having, or as being a carrier of an infectious disease will be permitted to enter the pool enclosure.

j. No person other than the bathers who have complied with these regulations, except the pool attendants, will be allowed within the pool enclosure.

(*Note*): *Exception is made in the case of the parents or those in charge of children using the pool.*

Regulations and instructions for pool attendants. Instructions relative to the operation of the pool, such as those dealing with the cleaning of the pool, the washing of the filter, and miscellaneous matters pertaining to operation alone, should be given by the officer in charge as the need for them arises. However, in order to facilitate the operation of the pool from an administrative standpoint, certain of the instructions and regulations governing the duties of pool attendants should be published by competent authority. The following regulations and instructions are examples of those that may be issued in the form of orders from higher authority:

a. The total bathing load for the pool is .... bathers and when this number of bathers have used the pool, it will be drained and cleaned. (*Applicable to the fill and draw pool*).

b. The maximum current load is .... bathers.

c. A residual chlorine content of from .... to .... parts per million will be maintained in the water of the swimming pool at all times.

d. One attendant (or ...... attendants) will be on duty within the pool enclosure at all times during the bathing period.

e. Only properly sterilized or laundered bathing suits and towels will be issued to bathers.

CHAPTER VIII.

FOOD CONTROL

ARMY RATION—FOOD VALUES—INSPECTION AGENCIES

The quality, quantity and character of the food are important factors in the maintenance and promotion of the health, morale and physical and mental efficiency of troops. Food may serve as an agency for the transmission of the pathogenic organisms and a diet which does not contain certain necessary food constituents may cause metabolic disturbances or the development of a deficiency disease. A ration which is either inadequate in general, or deficient in any food constituent, will cause an increased susceptibility to fatigue and produce physical and mental conditions which will interfere seriously with the maintenance of a high standard of training or of combat efficiency.

The Quartermaster Corps is responsible for the purchase and issue of all food supplies, including inspection and examination for compliance with purchase specifications. Officers of the Veterinary Corps of the Medical Department may act as technical advisors to purchasing officers in the conduct of specification inspections of foods of animal origin. Unit commanders are responsible for the care and preservation of the food after it has been issued to them by the Quartermaster Corps, and for the preparation and serving of the food.

Sanitary control. The Medical Department is charged with the responsibility of investigating the food supply of the troops in so far as it affects health, and with reporting upon and making recommendations for the correction of all defects or deficiencies which would affect the health of the consumer.

The sanitary control exercised by the Medical Department includes the following activities:

a. The inspection of food prior to or at the time of purchase, on receipt, in storage, at time of issue or in the kitchens and messes of the troops.

b. The supervision in an advisory capacity of the methods of handling, transporting and storing of food.

c. The supervision in an advisory capacity of the preparation of the food, including recommendations relative to the quantity and variety of the food prepared for the troops, the operation of kitchens and messes and the methods of cooking and serving the food in so far as these factors affect health.

d. The physical examination of food handlers for the presence of communicable diseases which are transmissible by food.

The army ration. A ration of food, as the term is used in connection with feeding troops, is the allowance of food for the subsistence of one man for one day. The quantity and character of the ration vary according to the conditions under which troops are operating. The garrison ration, which is the basic ration, is employed under conditions where administrative factors, climatic conditions, or military activities do not render it desirable to modify the quantity or quality of the food supply. The rations, other than the garrison ration, which are provided to meet exceptional conditions are the Filipino ration, the field ration, the travel ration and the reserve ration.

The ration consists of a number of component articles of food. The kind of components that form a ration and the quantity of each component are determined by the War Department. The components of the present ration (1936) are given in the following tables:

GARRISON RATION

Article	Quantity	
Meat:		
Bacon	Ounces	2.00
Beef, fresh	"	10.00
Chicken, fresh	"	2.00
Pork, fresh	"	4.00
Eggs, fresh	each	1.

Dry vegetables and cereals:		
Beans	Ounces	.50
Rice	"	.60
Rolled oats	"	1.50
Fresh vegetables:		
Beans, string, canned	"	3.00
Corn, canned	"	2.00
Onions	"	2.00
Peas, canned	"	2.00
Potatoes	"	10.00
Tomatoes, canned	"	2.00
Fruit:		
Apples, canned	"	1.50
Jam or preserves	"	.50
Peaches, canned	"	1.20
Pineapple, canned	"	1.20
Prunes	"	.30
Beverages:		
Coffee, roasted or roasted and ground	"	2.00
Cocoa	"	.30
Tea	"	.05
Milk:		
Milk, evaporated	"	1.00
Milk, fresh	"	8.00
Lard:		
Lard	"	.64
Lard substitute	"	.64
Butter	"	2.00
Flour, wheat	"	12.00
Baking powder	"	.09
Macaroni	"	.25
Cheese	"	.25
Sugar	"	5.00
Cinnamon	"	.014
Flavoring extract	"	.02
Pepper, black	"	.04
Pickles, cucumber	"	.16
Salt	"	.50
Sirup	"	.50
Vinegar	"	.16

TRAVEL RATION

Article	Quantity	
Bread, soft	Ounces	18.00
or		
Bread, hard	"	16.00
Beef, corned, or hash, corned beef	"	12.00
Beans, baked	"	4.00
Tomatoes, canned	"	8.00
Jam	"	1.40
Coffee, roasted and ground	"	2.00
Sugar	"	4.00
Milk, evaporated, unsweetened	"	1.00

RESERVE RATION

Article	Quantity	
Beef, corned	Ounces	7.00
Beans, with pork and plain sauce	"	8.50
Bread, hard	"	6.60
Chocolate, vanilla, sweetened	"	3.00
Coffee, soluble	"	.60
Sugar, granulated	"	2.40

The field ration is that prescribed for all persons entitled to a ration in time of war and whenever the ration-savings privilege is suspended. Its components are prescribed by the War Department or by the commander of the field forces.

Food value of the ration. The garrison ration is not intended to be issued as a complete ration under ordinary conditions, nor are all the components of the garrison ration, as such, issued to troops except in an emergency. The garrison ration establishes a means by which the money value of a ration at a given time and place can be determined by computing the cost of the complete ration at the place and during the time in question. A unit may receive from the quartermaster only a part or none of any one component of the ration and is then credited with the money value of the food not issued, as determined by the local cost of the article concerned. The ration money thus saved by the unit may be expended for articles of food not listed in the ration and which will serve to

balance the diet and provide the variety necessary to induce the troops to consume the proper quantity of suitable food.

The caloric value of the garrison ration is more than sufficient for all purposes. However, the caloric value of the food as actually served to the troops may vary widely, depending on the kind of food purchased in lieu of ration components and the efficiency of the methods used in its preparation. Given reasonable care in the selection of the articles of food and in their preparation, there is little danger that the ration as served to the troops will be lacking in caloric value under normal conditions.

The components of the garrison ration will not provide vitamin containing foods in sufficient quantities to maintain troops at their full physical efficiency. Additional vitamin containing foods must be supplied by the purchase of green vegetables, and other articles of food rich in vitamins and minerals, with money saved by the under issue of those components of the ration which are less desirable in this respect.

The component articles of the garrison ration will not, even when skilfully prepared and served, provide that variety of food necessary to avoid monotony and its consequent adverse influence on the morale and nutrition of the troops. Other articles of food must be purchased from ration savings, which, though they may have less caloric value than the ration components they replace, serve to produce a varied diet, and thus encourage the consumption of an adequate quantity of proper food.

The value of the consumed foods. The food value of the food served to troops is the value of the food they actually consume. Failure to consume a sufficient amount of suitable food may be due to one or more of several conditions, such as a lack of variety resulting in a monotonous diet, an inadequate supply of food served, failure to serve sufficient of any one constituent, or poor preparation of the food.

A monotonous diet, even though it contains an adequate supply of calories, vitamins, and minerals, and is balanced with regard to its constituents, will result in the consumption of a poorly balanced and inadequate diet by a large proportion of the troops concerned. Under such conditions, individuals tend to select from the menu offered only those foods which appeal to them and fail to consume adequate amounts of other

articles which they dislike or for which they have an aversion because of constant repetition.

Failure to supply the troops with a sufficient amount of food is ordinarily due, except in the event of a temporary emergency, to poor administration and is, therefore, correctible by administrative measures. The conditions arising from the poor preparation of food are likewise correctible by administrative and training procedures.

The consumption of insufficient food, or failure to consume an adequate quantity of any one of the constituents of a normal diet may not, and ordinarily will not, cause definite signs or symptoms of a food deficiency disease. It does, however, result in an impairment of the physical fitness of troops, or cause discontent and lowering of morale with the attendant decrease in ability to perform military duties.

The food value of a given ration is, therefore, not wholly determined by the caloric and vitamin content of its various component parts as issued, but by the food value of the articles of food consumed by the troops which in turn is governed by the method of preparing and serving the food and the variety of the diet.

FOOD CONSTITUENTS

The constituents of a food are protein, carbohydrate, fat, mineral substances, and vitamins. Each of the food constituents is required for the maintenance of physical well being and no one of them can be wholly replaced by another over any considerable length of time without danger to health.

The proteins, carbohydrates and fats are the nutrient constituents of the food. The primary function of protein is to supply the compounds required to rebuild the tissues that are being continually destroyed by the activities of the body. Carbohydrates and fats are the principal sources of the energy utilized by the body in the performance of work.

Protein. Proteins are contained in both animal and vegetable food materials. Lean meat and egg albumin are typical protein foods but protein is also present in varying amounts in milk, legumes, tubers, leafy vegetables and fruits.

Protein is broken down by the digestive and metabolic processes into its constituent amino acids. The individual amino

acids are in turn utilized by the body to repair and build body tissues, particularly muscular tissue. Each type of body tissue, such as muscle, bones or blood, requires certain specific kinds of amino acids for its growth and maintenance. Consequently, the value of a given protein as food is determined by the kind and number of amino acids it contains.

Milk, egg and meat proteins are complete in that they contain all the amino acids required by the human body. Other proteins, such as those derived from vegetables and fruits, are deficient in one or more of the necessary amino acids and no one vegetable or fruit will furnish all of the amino acids required in the metabolism of the body. However, a diet containing a variety of vegetable foods, or consisting of meat and vegetables, will usually provide all of the amino acids required, as those that are absent from one article of food will be present in another.

The quantity of protein required to maintain physical efficiency is relatively constant for a given individual. If more than sufficient protein is ingested, the excess is eliminated as nitrogen compounds, principally in the urine. If the supply of protein is deficient, either in quantity or quality, loss of body weight and impairment of physical efficiency will result. An average of about 45 grams (1.59 ounces) per day are required by the average man weighing 154 pounds. However, the average American diet contains from 100 to 150 grams (from 3.53 to 5.29 ounces) per day. The protein content of various articles of food is given in Appendices II and III.

Carbohydrate. Carbohydrates are contained in both vegetable and animal food but are derived principally from such articles of food as bread, potatoes, fruits, and cereals.

The oxidation of carbohydrate and fat in the body constitutes the source of power for physical work and, normally, about 65 per cent of the energy produced by the body is derived from carbohydrate ingested as food. If more carbohydrate is ingested than is needed by the body, a part of the excess is converted into fat and stored as such in the body. If the food contains an insufficient amount of carbohydrate, there will be a decrease in ability to perform physical work, metabolic disturbances may occur, and body fat and other tissues will be utilized to produce energy. Ingested protein may, to some extent, be utilized by the body to provide energy when the supply of carbohydrate and fat in the food is deficient.

However, physical efficiency and body weight are not maintained under ordinary conditions if the diet does not contain sufficient carbohydrate and fat.

As carbohydrate is the principal source of energy, the amount required will depend on a number of factors, including the physical activity of the individual, the climatic conditions, the character of the clothing and the body weight. Normally, the quantity in the diet varies from approximately 350 grams (12.35 ounces) to 700 grams (24.70 ounces). The carbohydrate content of the more common foods of the average diet is given in Appendix II.

Fat. Fat is present in greater or less proportion in most articles of food, but is derived principally from meats, fish, milk and milk products, and vegetable oils such as olive and cottonseed oil. Like carbohydrate, fat serves as a source of energy, although being less readily digested, absorbed and oxidized, it does not become available as a source of energy as quickly after ingestion.

If more fat is ingested than is needed by the body, some of it will be stored in the tissues where it constitutes a source of reserve energy which is drawn upon by the body when the food fails to supply the required amount of carbohydrate and fat. Stored fat also serves by its presence to protect and to support certain of the organs and other structures of the body.

While lack of sufficient fat in the diet can, to some extent, be compensated for by an excess of carbohydrate, the total absence of fat, or a long continued deficiency, will cause metabolic disturbances and a decrease in physical efficiency. The consumption of an excessive amount of fat will result in an increase in body weight due to the deposition of fat in the tissues of the body and may result in metabolic or digestive disturbances.

Theoretically, the allowance of fat can be reduced to a small quantity as compared with the amount which is usually included in a standard diet, provided the carbohydrate content is ample for the energy needs of the body. From a practical viewpoint, the diet should contain sufficient fat to maintain the fatty tissues of the body and in addition provide a source of reserve energy. Fat is also required in the preparation of many foods and as a flavor.

Generally, the average ration as served to the troops should supply from 75 to 140 grams of fat. Wide variations occur in the fat content of the food served in different messes and also in the quantity served on different days in the same mess, due principally to differences in the methods of preparing the food and in the character of the food served. Appendix II gives the fat content of various articles of food.

Caloric value of the food constituents. The caloric value of a food constituent is determined by complete burning or oxidation in a calorimeter under conditions which permit accurate measurement of the liberated heat. The average fuel values of protein, carbohydrate and fat when burned in a calorimeter are as follows:

Protein	5.65 calories per gram.
Carbohydrate	4.10 calories per gram.
Fat	9.45 calories per gram.

Within the body, however, a part of the food constituent ingested is lost in digestion or, as in the case of protein, it is not completely oxidized, and the caloric yield is less than when it is burned in a calorimeter. The average caloric values of the food constituents within the body, that is, the physiological energy values, are as follows:

Protein	4 calories per gram	(1814 per pound.)
Carbohydrate	4 calories per gram	(1814 per pound.)
Fat	9 calories per gram	(4082 per pound.)

Minerals. Certain of the mineral salts are necessary for the normal metabolic processes of the body. They also enter into the formation of all the tissues of the body and serve to maintain the proper chemical reaction of the body fluids. The minerals which are present in a satisfactory diet in appreciable quantities are calcium, phosphorus, potassium, sulphur, sodium, chlorine, magnesium, iron and iodine. Other minerals which are essential for metabolism, but which are present in the food only in minute quantities, are fluorine, silicon, copper, manganese, and zinc.

A diet which is deficient in one or more of the essential mineral salts will, if continued for a long period of time, produce metabolic disturbances. If the food contains excessive quantities of a mineral salt, the excess will, within limits, be excreted with no harmful results.

The exact quantities of the several mineral salts required by the body under varying conditions have not been definitely determined. A ration which is approximately balanced with regard to the meat, bread and vegetable components will contain sufficient of all the mineral constituents required by an adult, except that, in some instances, there may be a deficiency of calcium. The foods that are rich in calcium are milk products, eggs, beans, leafy vegetables and particularly carrots, cabbage and turnips. The minimum calcium requirement for the average man, weighing 154 pounds, is about one-half gram of calcium per day. The food consumed should provide approximately one gram of calcium per day, while the ration as prescribed frequently contains less than this amount. Consequently, care should be exercised in the formulation of menus to provide for calcium bearing foods. As a working rule, if the diet of an adult contains a sufficient amount of calcium bearing foods, it will provide an ample quantity of the other minerals required.

Vitamins. Vitamins are substances which by their presence in the body prevent certain functional disorders or deficiency diseases. In man the continued absence of a given vitamin from the diet will produce a specific avitaminosis manifested by characteristic symptoms of deficiency disease or metabolic disturbance. Advances are being made continuously in the knowledge of vitamins and from time to time the presence of new vitamins is proven and evidence is found which justifies the postulation of other vitamins. At the present time six vitamins are definitely known to exist. These are shown in the following table together with the disease or condition caused by the absence of each from the body.

Vitamin	*Disease or condition caused by deficiency of vitamin.*
Vitamin A	Hemeralopia, xerophthalmia, keratinization of the epithelium.
Vitamin B (B_1)	Beriberi, anorexia.
Vitamin C	Scurvy, malnutrition.
Vitamin D	Rickets.
Vitamin E	Sterility.
Vitamin G (B_2)	Pellagra.

While vitamins are classed as a group, each is specific and is not related to or interchangeable with any one of the others. Vitamins are nutrients rather than drugs and are obtained mainly from ingested food. The presence or absence of a given vitamin in a foodstuff is determined by bioassay methods based on the manifestation of characteristic metabolic or physiological disturbances when the material being assayed is fed to experimental animals under controlled conditions.

Vitamin A. Vitamin A is found associated with fats and was, for this reason, formerly known as fat-soluble A. Provitamin A, or the precursor of active vitamin A, occurs in plants as a yellow pigment called carotene. When a plant substance containing carotene is ingested by an animal, a part of the carotene is converted into the active form of vitamin A.

The quantity of vitamin A contained in any given material may be expressed in units, usually as International units, as determined by bio-assay methods (*supra*). The International unit is equal to the growth promoting quality of 0.0006 milligrams of beta-carotene. The International unit is equivalent to the U.S.P. XI unit. The Sherman unit is equal to 1.4 International units. Standard cod liver oil contains not less than 600 International units per gram. Material being assayed is checked against the U.S.P. reference cod liver oil which contains 3000 International units, or U.S.P. XI units, per gram.

Recently, a number of studies have been made by various workers with a view to measuring in units the quantity of vitamin A contained in different foods. For example, Eddy and Dalldorf in their book entitled "The Avitaminoses" state that the vitamin A concentration per ounce in butter ranges from 470 to 1,370 International units, in cow's milk from 30 to 100 units, in spinach 9,800 units and in carrots from 1,170 to 2,100 units.

The amount of vitamin A required by an adult to prevent avitaminosis has not been fully determined. A minimum allowance of 3000 Sherman units (4200 International units) per day for an adult, or 100 Sherman units (140 International units) for every 100 calories consumed has been suggested by some workers. In feeding troops these quantities should be regarded as the strict minimum, and larger amounts should be provided. There is no evidence that hypervitaminosis resulting from large quantities of vitamin A, or carotene, in the diet will cause any ill effects in the healthy adult.

In the army ration, the principal sources of vitamin A are milk, butter, eggs, green leafy vegetables, carrots, tomatoes, yellow corn, sweet potatoes, etc. The relative values in vitamin A of some of the different foodstuffs is shown in Appendix IV.

Vitamin A deficiency produces a somewhat more general effect than do deficiencies in other vitamins. Severe deficiency causes keratinization of the epithelium, notably of the eyes, and of the respiratory, gastrointestinal and urinary tracts. There is considerable evidence indicating that vitamin A deficiency lowers the resistance of the tissues to infection, especially to respiratory infections. When experimental animals are fed on a diet low in vitamin A content, there is an increase in the prevalence of calculi and calcareous deposits in the urinary tract.

Hemeralopia (night blindness) is the most important condition resulting from vitamin A deficiency in adults. Varying degrees of hemeralopia may be caused by a diet in which the vitamin A content falls below the requirement for the individual, but the diet need not be wholly lacking in the vitamin. It has been demonstrated that vitamin A deficiency is accompanied by an impaired ability to regenerate visual purple after exposure to light.

Xerophthalmia (keratomalacia) is due to keratinization of the epithelium of the eye and the para-ocular glands. It is characterized by an inflammation of the conjunctiva, which in untreated cases is followed by ulceration and necrosis of the cornea and blindness. The disease is more common in children than in adults, and in its early stages yields readily to treatment consisting of foods or compounds rich in vitamin A.

Vitamin A, or the provitamin carotene, is destroyed by high temperatures in the presence of oxygen or an oxidizing agent. However, the carotene in plant foods is not appreciably reduced in amount by the ordinary cooking or canning processes. Vitamin A is destroyed by dehydration accompanied by fermentation and oxidation, but is not affected by quick drying with destruction of the enzymes. The fermentation or oxidation of foods in storage will cause progressive destruction of vitamin A.

Vitamin B (*antineuritic vitamin*). The water soluble vitamin B has been found to be a complex substance from which vitamin B_1 has been isolated and identified. Vitamin B also contains another complex group of factors among which are vitamin G, or B_2 (*infra*, page 424), the postulated P-P body, and the anti-

dermatitis and growth promoting factors variously designated as lactoflavin, B_6, and vitamin H.

Vitamin B_1 is thermolabile and can be destroyed by cooking, especially if an alkali is added. However, if the food remains acid, only a relatively small part of the vitamin B_1 is destroyed by the low temperatures used in ordinary cooking. On the other hand, being water soluble, it is readily removed mechanically from the food in the cooking water, and is lost if the latter is discarded.

Vitamin B_1 is widely distributed in a number of foodstuffs, especially those of vegetable origin. Grains from which the embryo has been removed, such as milled or polished rice, are valueless as a source of vitamin B_1. The vitamin B values of different articles of food are shown in Appendix IV.

Various methods have been devised to express vitamin B_1 values in units. The International unit, as advocated by the League of Nations Vitamin Committee, is that amount of vitamin B_1 which is equal to ten milligrams of the International Reference Standard. The latter is prepared by adsorbing vitamin B_1 on fullers' earth according to a standard method. The Sherman unit is determined by feeding the substance to be tested to a standard test rat which has been depleted of vitamin B_1. One unit is that amount which will cause such a rat to increase in weight at the rate of three grams per week for four weeks.

The vitamin B_1 requirement for a given individual would vary according to age, basal metabolic rate, character of work, exposure to weather conditions, etc. A number of studies have been made and there is general agreement that the minimum requirement for the average adult under average conditions is about 200 International units per day. There is no evidence that an excessive amount of vitamin B_1 will cause any ill effects.

A diet deficient in vitamin B_1 to an extent which causes continued depletion over a considerable period of time will cause beriberi (polyneuritis) (page 1027). Experimentally, a diet in which the vitamin B_1 content is inadequate to a varying degree may not cause frank symptoms of beriberi, but is frequently accompanied by other conditions due to deprivation of vitamin B_1. Among these are more or less severe anorexia, interference with carbohydrate metabolism, and neuritis of various types. In children vitamin B_1 is essential in promoting optimum growth.

The dietary habits and the ration of American troops are such that beriberi, as a disease entity, would never occur under normal conditions. Nevertheless, care must be taken that the food consumed by troops provides an ample supply of vitamin B_1. Any inadequacy in this respect may cause the development of pre-beriberi conditions with loss of appetite, a lessened resistance to fatigue and, possibly, general weakness. A ration low in vitamin B_1 will not only have an adverse effect on the physical fitness of the troops, but may be an important factor in lowering their morale.

Vitamin C (*antiscorbutic vitamin*). Vitamin C, or ascorbic acid, is a water and alcohol soluble substance present in certain fruits and vegetables (Appendix IV). The citrus fruits, tomatoes, and raw cabbage are examples of foods having high vitamin C values. Meat and eggs contain very little vitamin C. Milk may be rich or poor in vitamin C depending upon whether or not the cows producing the milk are given feed containing vitamin C.

Vitamin C is rapidly destroyed by heat and oxidation, although the proportion lost and the rapidity of destruction varies with different foods. Ordinary cooking destroys much of the vitamin C, unless the cooking time is very short or measures are taken to prevent oxidation. Aging and dehydration will destroy the vitamin C if oxidation also occurs. Methods are available for canning or processing foods which will prevent any great loss of vitamin C. Like vitamin B_1, the vitamin C is water soluble and is therefore easily extracted and lost in the cooking water.

The International unit of vitamin C is 0.05 milligrams of l-ascorbic acid (pure vitamin C). According to the estimates made by various workers, the amount of vitamin C required daily by an adult ranges from 400 to 800 International units, or from 20 to 40 milligrams of ascorbic acid. There is no evidence that an excess of vitamin C is harmful.

Vitamin C prevents scurvy and is also an important factor in maintaining normal nutrition. While avitaminosis C will cause scurvy where depletion is relatively severe, lesser degrees of deprivation will cause a pre-scorbutic condition, or subclinical scurvy, manifested by lowered resistance to infection and to fatigue, physical weakness, anemia and a tendency to capillary hemorrhages. In the case of troops, any depri-

vation of vitamin C would seriously impair the morale of the organization.

The ration of American troops ordinarily contains sufficient vitamin C foods, but, nevertheless, care should be taken that the supply is ample.

Vitamin D (*antirachitic vitamin*). When ergosterol, cholesterol, and possibly other sterols, are irradiated with ultraviolet light of given wave lengths, an antirachitic substance is produced which is called vitamin D. Ergosterol, cholesterol, and the other sterols are the provitamins, or the precursors of vitamin D. Vitamin D, or its precursors, is found in certain oils and fats, notably in the oils obtained from the livers of cod, halibut and other fish. Egg yolk is a source of vitamin D. Vegetables are as a rule deficient in vitamin D, but may contain small quantities. Irradiated yeast is rich in vitamin D. Vitamin D milk (page 559) is the most dependable source of vitamin D, and milk is the only common food which when fortified with vitamin D will be considered for acceptance by the Council on Foods, American Medical Association. A number of pharmaceutical compounds containing definite quantities of vitamin D are available.

Vitamin D is one of the important factors in the formation of normal bone, and is, therefore, essential in the prevention of rickets in children. As vitamin D appears to be a necessary factor in maintaining a normal calcium and phosphorus metabolism, probably throughout life and not only during infancy, the ration for troops should contain sufficient vitamin D foods.

There is some evidence indicating that vitamin D from animal sources is more potent than that obtained from vegetable sources. Vitamin D of animal origin is found principally in irradiated milk and in milk from cows fed on irradiated yeast (page 559). The main sources of vitamin D of vegetable origin are foods containing irradiated ergosterol, such as irradiated yeast or milk fortified by the addition of an irradiated ergosterol compound.

The International unit for vitamin D is based upon and is equal to the activity of one milligram of the International standard solution of irradiated ergosterol, or the equivalent quantity of U. S. P. standard reference cod liver oil. Bioassay methods are used with the rat as the test animal. One

International unit is equivalent to one U. S. P. XI unit or 0.37 of a Steenbock unit.

Cooking or storage apparently does not affect the stability of vitamin D in foodstuffs.

The vitamin D requirement for adults has not been determined. It is generally considered that milk containing 400 U.S.P. XI units per quart will provide sufficient vitamin for the normal infant when fed in the usual quantities. Where the milk contains only 135 units per quart, it is probable that infants will require additional vitamin D (page 559).

Enormous doses of vitamin D might produce harmful results by causing an increase in blood calcium with the deposition of calcium in the walls of blood vessels and organs.

Vitamin G (*Vitamin B_2, antipellagra vitamin*). Vitamin G is a thermostable factor found associated with vitamin B_1 in natural foodstuffs. Vitamin G, as now known, may be a complex substance including other vitamins or factors not yet isolated. It is apparently a pigment of the flavine type.

It is thought by many workers that vitamin G is an important factor in the prevention of pellagra, and that a diet deficient in vitamin G will cause pellagra. Vitamin G is also essential in promoting normal nutrition. Experimentally, a diet inadequate in vitamin G will cause a dermatitis. A shortage of vitamin G has been found to be associated with a pellagra-like condition known as black tongue in dogs. Cataracts have been produced in white rats by feeding them a diet deficient in vitamin G.

The best sources of vitamin G are milk, liver, eggs, lean meat and green vegetables. Generally, a diet which supplies sufficient vitamin B_1 will also provide the required amount of vitamin G.

The vitamin G requirement for an adult has not been determined. A unit of measurement has been devised, known as the Sherman unit, or the Sherman-Bourguin unit. There is no International unit. The Sherman unit is that amount of vitamin G which when fed to a depleted test rat will cause a gain in weight of three grams per week for four weeks.

Vitamin G is not destroyed by ordinary cooking temperatures, but is readily extracted from the food in the cooking water. In this latter respect it resembles vitamin B_1 and vitamin C.

Vitamin E. Vitamin E is a fat soluble factor which is in some way concerned with reproduction or sterility. It is

found generally in green leaves and seeds, and is probably present in other natural foods. It is most abundant in oil expressed from wheat germs.

There is, as yet, no evidence that vitamin E is essential to the nutrition of man.

Summary of the vitamin and mineral requirement of troops. During peace any ration provided for American troops will contain sufficient quantities of vitamins and minerals to prevent the occurrence of definite symptoms of deficiency disease. This same situation will also prevail during war, except possibly under conditions of extreme stress, when the system of supply fails to function, or during a siege. However, there is little doubt that there are times during both peace and war when the troops do not receive optimum amounts of vitamins and minerals. Under these circumstances, there must occur impairment of physical and mental health, with various subclinical manifestations of deficiency disease. In some instances, an inadequate supply of vitamins, especially vitamin B_1, causes loss of appetite and thus establishes a vicious circle with continuing failure to consume the proper foods. A supply of vitamins and minerals which theoretically meets the minimum requirements may for various reasons be insufficient to prevent lowered resistance to infection, with the consequent adverse effect on the healing of wounds and probably also on the prevalence of some of the respiratory diseases. There is sufficient evidence to justify the belief that anything less than a fully adequate supply of vitamin and mineral containing foods causes increased susceptibility to physical and mental fatigue, with loss of efficiency in the performance of military duties and a lowering of morale.

Broadly speaking, because of the dietary habits and customs of the American people, the ration for American troops is based on bread, meat and potatoes. These components provide the energy requirements, but they must be supplemented by foods containing the necessary vitamins and minerals, if the physical fitness and mental health of the troops are to be maintained. Mess officers and mess sergeants cannot be expected to know, and to consider, the confusing and complex vitamin and mineral requirements of the body. Lacking skilled guidance and supervision in this respect, the usual army mess provides a minimum of

the vitamin and mineral containing foods in addition to the basic components mentioned above.

In practice, the army ration is in part a money ration, and the troops must be fed with the money allotted for that purpose. Milk, butter, eggs and fresh vegetables are expensive, and money to purchase additional quantities must be obtained from ration funds. Consequently, unless the mess officer realizes that such foods are necessary, there is always a tendency to save money by purchasing cheaper foods. Also fresh green vegetables and fresh fruits are more difficult to prepare than the canned products and for this reason many army cooks prefer the latter.

In war, the difficulties of transportation may make it impracticable in some situations to supply the necessary vitamin and mineral containing foods. However, past experience indicates that at least the troops in training and rest areas can be supplied with ample quantities of these foods.

In so far as providing vitamins and minerals is concerned, the objective sought in operating an army mess is to provide the *optimum* supply of foodstuffs containing vitamins and minerals. The requirements of different individuals are too indefinite and the effects of a shortage of either vitamins or minerals are too far reaching to justify providing the troops with rations which meet only the minimum requirements for vitamins and minerals. In other words, the supply of these foods must be ample, and not barely sufficient in units or quantities as set forth in the literature on this subject.

The foods which must be given to the troops in order to provide them with the necessary vitamins and minerals include fresh milk, butter, eggs and *fresh, green* vegetables. In cooking the vegetables care must be taken to prevent loss of vitamins by heat, oxidation or in the cooking water (*supra*). The vegetables must be those having *green* leaves, such as cabbage, carrots, spinach, lettuce, etc. They must be *fresh*, as many of these vegetables lose a considerable part of their vitamin content in storage.

FOOD REQUIREMENTS

The total food requirement is usually expressed in terms of calories derived from the nutrient food constituents. This method assumes that the nutrient food constituents, as supplied, will contain the proper kind and an adequate quantity of vitamins and

mineral salts, and in stating the value of the diet in calories it is assumed that the diet is balanced in all respects.

The energy required for the maintenance and physical activites of the body is derived from the oxidation of the ingested food. With the body at absolute physical rest, in so far as voluntary movement is concerned, a certain definite amount of energy is expended for the maintenance of body temperature and the involuntary movements of the body, such as those pertaining to respiration, the circulation of the blood and other internal processes. The energy thus expended is derived from the basal metabolism, and is required as long as life exists.

The basal metabolism varies with the weight of the body but in a healthy individual it is constant within the limits of experimental error for a given body weight. Increased physical activity above that of absolute physical rest produces a proportional increase in the energy requirement. The food intake must, therefore, be sufficient to provide for basal metabolism and for any additional physical activity. If the food supply is insufficient, the body tissues are oxidized to provide the required energy.

The experimental food requirement. The diet required by healthy individuals varies with the amount and kind of physical activity, body weight and dietary habits. The quantity of food, and the relative proportion of the nutrient food constituents necessary to maintain physical efficiency, and to provide energy for a given amount of physical activity under fixed conditions can be experimentally determined. Theoretically, a man weighing 70 kilograms (154 pounds) will require approximately the quantities of food and nutrient food constituents shown in the following table, under the conditions as given regarding physical activity.

Theoretical quantity of food and food constituents required by a man weighing 154 pounds.

	Protein		Fats		Carbohydrates		Total
Physical Activity	Grams	Ounces	Grams	Ounces	Grams	Ounces	Calories
Light work	100	3.53	50	1.76	525	18.52	2950
Medium work ...	125	4.41	75	2.65	625	22.05	3675
Heavy work	150	5.29	100	3.53	700	24.70	4300

The food allowance. In feeding troops consideration must be given to factors which render it necessary to increase the quantity of food provided beyond that which will, theoretically, meet their metabolic requirements. The food allowance must always be greater than the theoretical food requirements. The quantity and character of the food consumed by troops under average service conditions will vary within limits with the nature of the work, the manner and methods of preparing and serving the food, the dietary habits of any considerable proportion of the group concerned, the variety of the food articles served, or variations in climatic conditions. Increased physical activity will render additional food necessary to supply the increased energy demand. A poorly balanced diet may result in the decreased consumption of one food constituent with an increased consumption of others or a decrease in the total food intake.

Changes in the occupational environment may modify the food allowance. Recruits, as a rule, will eat more food than trained troops until they become accustomed to the physical activities of the military service. Troops in the field who are subjected to cold or rain will require a larger allowance of food than those in permanent stations or camps.

The food allowance for troops must also provide for a certain amount of wastage, which, even though it is small in well operated messes, always occurs in some degree.

Under practical conditions, troops must be provided with sufficient food to satisfy their hunger without reference to the caloric value. The caloric value of the garrison ration as served varies considerably from day to day according to the nature of the food articles that are substituted for the ration components. Usually, soldiers in training, in camps, or garrisoned in stations will require a diet yielding approximately 3500 calories per day. Marching troops, or troops in combat, require a greater allowance of food, and under these conditions a ration yielding from 4000 to 5500 calories must be supplied. Conversely, men engaged in duties of a sedentary nature, such as hospital, office or laboratory work, require a smaller food allowance than those whose duties are of a more strenuous character.

A balanced diet is a diet that is so prepared and served that the troops will consume a sufficient quantity of each of

the food constituents, and which will not, because of non-acceptability, be detrimental to morale. The factors concerned in the preparation of a balanced diet for troops are the kind and quality of the food articles constituting the ration, the methods of preparing the food, the variety of food offered in the diet, and the methods of serving the food.

Any diet, in order to be balanced, must primarily contain an adequate quantity of each of the five food constituents, that is, of protein, fat, carbohydrate, vitamins and mineral salts. It is not necessary, nor is it practicable, to prepare each meal or the ration for each day so that the food constituents are balanced, but the food consumed during a given period of time, for example one week, should constitute a balanced diet.

While a ration may contain the different food constituents in the proper proportions when issued, any one of several conditions may serve to prevent the ration as consumed by the troops from being properly balanced. Such a ration may be converted into a poorly balanced diet by faulty preparation which will render one or more of the components non-acceptable to the group served; a lack of variety or the continuous serving of some one food or similar foods may prevent the consumption of a necessary constituent, or the food may be served in such a manner that troops will not accept some articles that are essential to a balanced diet.

A diet entirely acceptable to the group concerned is essential in the maintenance of morale and a diet containing elements which are non-acceptable is, in effect, a poorly balanced diet, even though it contains the necessary quantities of the several food constituents. Non-acceptability is usually due to the inclusion in the ration of articles which do not appeal to the group appetite and for which the troops served have an averison. In other instances, the continuous or too frequent serving of some food may produce an aversion to an otherwise acceptable article of the ration.

A poorly balanced diet, if long continued, tends to cause physical impairment, the nature of which will depend on the kind of dietary deficiency. A diet which does not cater to the group appetite, to the extent of being acceptable to the majority of the troops, because of its monotonous character, or faulty preparation or serving, will cause discontent and

lowered morale. The mental states thus produced promote susceptibility to fatigue, and lessen physical and mental efficiency. Further, a diet which does not meet the demands of the group appetite may also be a factor in the transmission of disease through food, in that the troops will supplement their ration by the purchase of food from uncontrolled and, at times, dangerous sources.

DISEASES CAUSED OR TRANSMITTED BY FOOD

The diet may be the primary cause of a disease either because it fails to supply, or provides only an inadequate quantity of a food constituent, or the food may serve as a transmitting agent for the causative organisms of certain of the infectious diseases.

Those diseases which are produced by a deficient diet are classified generally as deficiency diseases (page 418). They are caused by the lack of an essential food factor and are preventable and curable by a balanced diet.

Any disease, the causative organisms of which can be conveyed by the food to a point of invasion within the body, may be transmitted by food. The diseases most frequently transmitted in this manner are those belonging to the intestinal group, such as typhoid fever, the food infections, dysenteries and diarrheas, but food may also be the transmission agency for other diseases, such as tuberculosis, scarlet fever and diphtheria. Diseases due to a pre-formed toxin, of which botulism is an example, may be caused by food in the sense that the food carries the toxin from the point of origin in infected food to the alimentary tract of man.

Poisoning may be caused by certain plants of which mushrooms, or rye contaminated with ergot (a parasitic fungus, *Claviceps purpurea*), are examples. Poisoning may also result from the ingestion of food containing chemical poisons.

DISEASE TRANSMISSION BY CONTAMINATED FOOD

Contaminated food is food which contains pathogenic organisms or the toxic products of such organisms. Food products may be unsuitable for consumption because of contamination with pathogenic organisms or their products, spoilage, the presence of chemicals, or inherently poor quality.

The effect of food containing pathogenic organisms, or their products, on the health of the consumer depends on the pathogenicity of the contaminating organisms, the degree of contamination, and the immunity or resistance to infection of the individual consumer. Organisms of low pathogenicity may not produce diagnosable clinical symptoms of a disease entity, or the number of organisms or the amount of toxin present may not be sufficient to produce frank symptoms. Certain individuals may possess to a greater or less extent an immunity or resistance to the infection which will prevent the occurrence of symptoms. It is for one or more of these reasons that when a group of persons or a body of troops consume contaminated food from the same source not all the individuals exhibit symptoms of the disease.

Where food is contaminated prior to cooking, the cooking processes to which it is subsequently subjected may, and frequently do, destroy the disease producing organisms or toxins and render the food safe for consumption.

Kinds of contamination. While food may be contaminated with many kinds of organisms, the diseases most frequently caused by contaminated foods are those belonging to the intestinal group (page 13). This is due first, to the facility with which the causative organisms or toxins of intestinal diseases contained in ingested food can reach and invade the tissues of the intestinal tract, and second, to the fact that the conditions under which food products are obtained, prepared and served favor the introduction, continued existence and growth of certain of the etiological agents of intestinal disease. Diseases other than those belonging to the intestinal group, such as septic sore throat, diphtheria, scarlet fever or tuberculosis, may be transmitted by food but, except in the case of septic sore throat, food constitutes merely an incidental and not the usual or principal agency of transmission.

Contaminating organisms. The pathogenic organisms most commonly found in food include members of the *Salmonella* group (*S. enteritidis, S. aertrycke, S. suipestifer, S. schottmuelleri* and *S. paratyphi*), the typhoid bacillus, the tubercle bacillus, the various types of the dysentery bacillus, the diphtheria bacillus, hemolytic streptococcus, the strains of staphylococcus that cause food infection, *Brucella melitensis, Brucella abortus,* and

Clostridium botulinum. In some instances, a pre-formed toxin is transmitted by the contaminated food.

Endameba histolytica, the etiological agent of amebic dysentery, is the most important of the pathogenic protozoa transmitted by contaminated food. Other protozoa which may be transmitted by food are *Giardia intestinalis, Trichomonas hominis, Chilomastix mesnili* and *Craigia hominis.* These are parasitic flagellates found in the intestinal tract of man which may cause diarrhea, but there is no absolute proof that any of them are pathogenic.

A number of the parasitic worms can be transmitted in their infective stages by food. The more important of these parasites are *Trichinella spiralis,* the causative agent of trichinosis, and certain species of tapeworms, such as *Taenia saginata* (the beef tapeworm), *Taenia solium* (the pork tapeworm) and *Diphyllobothrium latus* (the fish tapeworm).

Sources of contamination. In the case of food products of animal origin, the contamination may be derived from a diseased animal. Thus, the flesh of animals suffering from diseases such as septicemia and diarrhea, or from puerperal fever or tuberculosis, may serve to transmit pathogenic organisms to the consumer. The milk from tuberculous cattle may contain and transmit tubercle bacilli.

Any food substance which will not destroy the organisms by antiseptic action may become contaminated by contact with infective material. The hands of sick persons or carriers of disease may convey the organisms to the food of others; the water used in the preparation of food or in washing utensils may constitute a source of contamination, or food may be contaminated by contact with dust or other extraneous material containing the etiological agents of disease.

Organisms introduced into preserved foods may produce toxins which, when ingested, cause disease, such as, for example, *Clostridium botulinum.*

PREVENTION OF DISEASE TRANSMISSION BY FOOD

The prevention of disease transmission by food is accomplished by adequate and timely inspection of food products and the rejection of those unsuited for consumption, and the employment of facilities and procedures in the handling, preparation

and serving of food which will obviate contact with infected materials or contamination with pathogenic organisms.

The food products that are routinely inspected for the purpose of detecting conditions which render them unsuitable for food are:

a. Meat and meat products.
b. Poultry and eggs.
c. Fish and shellfish.
d. Milk and milk products.
e. Canned foods.
f. Fresh vegetables and fruits.

Ordinarily, such foods as sugar, cereals, salt, or spices, are not inspected for deficiencies which would impair health.

Inspection agencies. Food supplies for the army are inspected by both military and civilian agencies. The inspections made by military agencies do not ordinarily duplicate those performed by competent civilian agencies but are an extension and continuance of such inspections.

Civilian agencies. Civilian food inspection agencies may be divided into two groups, first, those that operate under federal laws and, second, those that function in accordance with local laws and regulations as promulgated by state, county or municipal authorities.

Federal food inspections are conducted under authority granted by the Federal Pure Food and Drug Act and the Federal Meat Inspection Act of June 30, 1906, and amendments thereto, and are restricted to foods which are produced or prepared for interstate or foreign commerce. Food products sold within the state in which they are produced are not subject to inspection by any federal agency, except that, under certain conditions, an establishment and all the food articles manufactured or prepared in such establishment are subject to federal inspection if any such articles are to be shipped to another state or to a foreign country, even though the articles so shipped are only a portion of those produced and the remainder are sold within the state.

Inspections conducted by local civilian agencies vary greatly in scope and thoroughness according to the nature of the local laws and regulations and the policies of the inspecting authorities.

Military agencies. The Quartermaster Corps is responsible for the purchase and issue of all food supplies and is therefore the primary food inspection agency for the army. However, Quartermaster Corps inspections are made primarily to determine if the food supplies in question comply with required specifications for purchase or acceptance and include consideration of features which would affect the health of the troops only when such features are included in the specifications. Quartermaster Corps inspections are usually made prior to purchase or acceptance or at the time the food supplies are received by the army.

The Medical Department, and particularly the Veterinary Corps of the Medical Department, conduct those inspections the principal purpose of which is to detect and eliminate foods which would be detrimental to the health of the troops, or which deal with the sanitary aspects of the environment in which food for the troops is produced or handled.

Scope of inspections. Food inspections are classified generally as to type and extent as follows:

a. The inspection of establishments in which food is produced, prepared, transported or stored for environmental conditions which are actual or potential factors in the contamination of the food.

b. The inspection of food supplies to determine the presence or absence of causative agents of disease, or of substances or conditions which would render the food deleterious to the health of man or unwholesome or otherwise unsuitable for consumption.

c. The inspection of messes, including the adequacy and suitability of the diets, the methods of and facilities for preparing and serving the food, and the health of food handlers.

Place and time of inspections. The place and time that a food inspection is made depends on the conditions surrounding the procurement, issue and preparation of the food in question. If food is purchased for immediate issue and preparation for consumption, inspection may be required only at the time and place of purchase. If food is purchased for future delivery and consumption, repeated inspections may be

required to insure that the food remains free from contamination until consumed by the troops. Food inspections are classified generally as to time and place as follows:

a. Inspection prior to purchase or procurement by military authority.

b. Inspection on receipt by the army.

c. Inspection during storage under military jurisdiction prior to issue or prior to shipment from one station to another.

d. Inspection at time of issue to the troops.

e. Inspection in kitchens prior to or during the process of preparation for consumption.

CHAPTER IX.

MEAT INSPECTION

The term meat inspection, as it is generally used, pertains only to the inspection of food animals, principally cattle, sheep, hogs and goats, and meat products obtained from such animals. It does not include the inspection of poultry and fish. Meat inspection includes the following activities:

a. The inspection of establishments.
b. Ante-mortem inspections.
c. Post-mortem inspections.
d. The inspection of meat products.
e. The inspection of meat and meat products in kitchens and messes prior to or at the time of preparation or serving.

All phases of meat inspection include supervision by the inspector of the sanitary conditions of establishments where food animals are slaughtered or meat products are produced, handled, or stored.

Federal meat inspection. The Act of June 30, 1906, as amended, provides for the inspection by the Bureau of Animal Industry, Department of Agriculture, of all meats intended for interstate commerce or foreign trade. The immediate purpose and effect of the federal meat inspection law is to prevent interstate or foreign commerce in contaminated or unwholesome meat products. The ultimate effect is to prevent the consumption of meat products derived from diseased animals or which have been produced under insanitary conditions. Army Regulations 40-2150 require that only meat which has been subjected to and passed by federal inspection shall be issued to troops, except where such meat is not obtainable.

Scope of the Federal Meat Inspection Law. Under the federal law, federal meat inspectors and employees inspect and supervise the sanitary conditions of the establishment in which the animals are confined or slaughtered or in which meat products are prepared, handled or stored; make ante-mortem and post-mortem inspections for disease conditions; inspect and supervise the manufacture of meat products or any food article containing meat, and operate laboratories for the examination and analysis of meat and meat products.

Condemnation and passing. All condemned meat must be destroyed or so treated that it cannot be used for food and all acceptable meat is stamped or otherwise marked with the statement "U. S. Inspected and Passed."

Coordination of federal and army inspections. Army inspectors should consider meat or meat products which have been inspected and passed by federal meat inspectors as suitable for food at the time and at the place where it was inspected and passed. The activities of the army meat inspectors should not duplicate or conflict with those of the federal inspectors but should begin where and when the products concerned pass from the jurisdiction of the Federal Government.

While acceptance by federal health inspectors is assurance that the meat has been produced under sanitary conditions and that ante-mortem and post-mortem examinations failed to reveal evidence of diseases communicable to man, it does not guarantee that meat or meat products as received by the army are sound and free from contamination. Such meat may have become contaminated by handling, or spoilage may have developed as a result of poor refrigeration or faulty storage subsequent to federal inspection.

State or municipal meat inspection. Meat intended for sale within the state in which it is produced, and which is not therefore subject to the federal meat inspection law, may be inspected by agencies established by state or municipal governments. Where the inspection and supervision by such agencies is adequate and reliable, the results may be accepted by the army to the same extent as the results of federal meat inspection. Whether or not the results of state or municipal inspections are acceptable for army purposes must be determined in each instance by army authorities.

Meat inspection by army inspectors. The surgeon of a command is responsible, from an administrative viewpoint, for the inspection of meat supplies for conditions which would be deleterious to the health of the troops. These inspections are, however, usually made by a veterinary officer under the administrative supervision of the surgeon. When veterinary officers are not available for duty as meat inspectors, the necessary inspections are made by medical officers.

The inspections made prior to receipt of the meat by the using organization are ordinarily conducted by veterinary officers, and not by medical officers. Medical officers are frequently required to inspect meat in kitchens and messes and they may, at times, inspect meat products in the possession of the army and prior to issue to the using organizations. Medical officers are seldom required to make ante-mortem or post-mortem inspections. They should, however, be conversant with the nature and scope of ante-mortem, post-mortem and meat products inspections as made by veterinary officers in order that they may determine the effect which such inspections may have on the scope and character of any subsequent inspections which they may make.

Establishment inspection. Medical Department officers are not ordinarily required to make inspections of establishments which are engaged in interstate commerce, and, therefore, under the jurisdiction of the federal meat inspection law, as the findings and reports of the federal meat inspectors can be accepted in lieu thereof.

Generally, the civilian establishments which are inspected by Medical Department officers engage in local rather than interstate trade. These establishments include such facilities and places as abattoirs, slaughtering pens and houses, refrigerator cars, butcher shops, markets, storehouses or rooms, or places devoted to the manufacture or storage of meat products of various kinds. The principal purpose of the establishment inspection is to determine if the meat supplies are produced, handled or stored under such conditions that they will remain free from contamination. In scope, it includes a study of the environment for actual or potential sources of contamination and of the corrective measures required.

Where the supervision exercised by army inspectors includes continuous control, as provided by veterinary ante-

mortem and post-mortem inspections and supervision of the manufacture of meat products, establishment inspection and supervision is usually a routine part of such control. In other instances, establishment inspection may be a separate procedure which is conducted periodically, or as required.

Under the federal law, meat or meat products cannot be prepared, handled or transported for interstate commerce in or by an establishment which does not comply with the sanitary regulations as promulgated by federal authority. Specifically, the federal authorities refuse to grant inspection until sanitary requirements are complied with and thus deny the operator of such an establishment the right to engage in interstate commerce.

Municipal and state laws usually require a permit for the operation of an establishment. In order to secure or retain a permit, the operator of an establishment must comply with the rules and regulations concerning sanitation and a permit may be refused, suspended or revoked for failure to observe such rules and regulations.

An establishment under the jurisdiction of the army is operated in accordance with regulations and orders issued by the proper military authority.

The establishment inspection should include, where applicable, the following general factors which are subject to modification to meet the requirements of the existing local situation.

Enforcement of regulations or orders. The determination of the degree to which rules, orders or regulations issued by competent authority are enforced and the manner and methods of enforcement are important parts of an establishment inspection.

Nuisances. The existence of nuisances should be considered, including the presence of putrescible material, drainage, and general cleanliness.

Disposal of wastes. Facilities for floor drainage, such as floor drains, gutters, and plumbing, and their effectiveness. The type, condition and location of toilets and lavatories. The methods and appliances employed to dispose of solid wastes, such as garbage, condemned meat, offal, manure, or rubbish.

Water supply. The quality and adequacy of the water supply.

Ventilation. The type and efficiency of the ventilating system, with particular reference to the presence of dust, odors or excessive humidity.

Apparatus and equipment. The adaptability and suitability of the equipment, utensils and appliances. The methods utilized and the facilities available for cleaning and, where indicated, for the disinfection of equipment and apparatus.

Means of separating edible and contaminated products. The means and facilities utilized to prevent contact between condemned carcasses, parts of carcasses or meat products, and the meat which has not been inspected or has been passed as acceptable.

Insects and rodents. Methods used to prevent access to the meat by flies, cockroaches or other insects, and by rats or mice.

Refrigeration and cold storage. The suitability and adequacy of facilities for refrigeration, cooling and cold storage of meat products and the efficiency of the methods employed in operating them.

Storage and packing. The methods employed to prevent contamination of meat products during storage and during and after packing.

Employees. The employees who handle the meat in any form should be observed for cleanliness, habits which would tend to spread contamination, and evidence of disease. If rules or regulations have been promulgated requiring employees, as food handlers, to be physically examined, the manner of enforcing such rules or regulations should be determined.

ANTE-MORTEM INSPECTION

An ante-mortem inspection is an examination of a food animal prior to slaughter for diseases or conditions which would render its flesh unsuitable for consumption. It also includes a sanitary inspection of the yards, pens, or cars in which the animals are handled.

Ante-mortem inspection is usually made prior to purchase but may be made on receipt of animals purchased on the hoof. It may be performed on the premises of the owner of the animals before they are bought by the government, on the military reservation at the time of delivery, or at the slaughtering establishment.

A preliminary ante-mortem inspection may be performed for the purpose of determining the condition of the animals prior to purchase or at the time of receipt or delivery. A final ante-mortem inspection should be made within 24 hours prior to slaughter.

Primarily, the ante-mortem inspection of food animals is made for the purpose of detecting and rejecting animals having diseases which might be communicated to the consumer of the meat, especially those conditions that can be diagnosed in the

FIG. No. 103. Ante-mortem inspection. Separation of a suspect from other animals. (Courtesy of the Bureau of Animal Industry, U. S. Dept. of Agriculture, Washington, D. C.).

live animals but are difficult to detect by post-mortem examination. The ante-mortem inspection also includes search for evidence of such conditions as immaturity, advanced pregnancy, recent parturition, fatigue, exhaustion, or injuries.

Conduct of ante-mortem inspections. In the conduct of ante-mortem inspections of food animals, all animals are carefully observed for evidence of disease, particularly tuberculosis, septic conditions, anthrax, hog cholera, or splenetic fever. The body temperature of suspected animals should be taken and recorded.

Any evidence of fatigue or exhaustion should be noted and the slaughter of animals affected by these conditions should be delayed for from six to twelve hours. If tired animals are killed before being rested, bleeding may be incomplete and the quality of the meat impaired. The flesh of fatigued or exhausted animals may also contain toxic bodies which are harmful to man.

Army meat inspectors should be familiar with the local laws and regulations relative to the management of cases of communicable disease, and such laws and regulations should be complied with in all instances.

As a result of an ante-mortem inspection, animals may be passed for slaughter, rejected outright, tentatively rejected pending further observation, or passed for slaughter as suspects with decision reserved until after the post-mortem inspection.

Passed for slaughter. Animals showing no indications of disease or other abnormal conditions which would render their flesh unsafe or undesirable for food are passed for slaughter. However, as certain diseases are difficult to detect by ante-mortem inspection and as disease may develop or injuries occur subsequent to inspection and before slaughter, acceptance prior to slaughter does not obviate the necessity for post-mortem inspection.

Outright rejection. Animals should be rejected outright for food purposes at the time of ante-mortem inspection if they present evidence of diseases or other abnormal conditions that would cause post-mortem rejection. Some of the more common causes for outright rejection as a result of ante-mortem inspection are positive reaction to the tuberculin test, tetanus, blackleg, splenetic fever, railroad sickness, or advanced scabies. Moribund animals or those dead from causes other than slaughter should be rejected outright.

The disposition of animals rejected outright at ante-mortem inspection depends on the circumstances and the nature of the cause for rejection. Dying animals and those that have diseases communicable to other animals or to man should be destroyed. If desirable from an economical point of view, animals rejected outright for food purposes because of injuries, disease which will yield to treatment, or other curable conditions, may be released for purposes other than food. The carcasses of animals destroyed because of conditions found at ante-mortem inspection may be tanked, incinerated or treated with some denaturing substance, such as a phenol compound, oil, or quick lime, and buried. The carcasses of animals found to have anthrax should be completely incinerated, or tanked.

Tentative rejection. Animals may be tentatively rejected at ante-mortem inspection for conditions which temporarily render them unsuitable for food or which cannot be definitely diagnosed without further observation. Animals that have been in contact with cases of communicable disease may be held in isolation for observation until the disease develops or until the end of the incubation period of the disease in question. Animals having a communicable disease which can be cured in a short time may be held until they recover and then passed for slaughter.

FIG. No. 104. Animal being tagged as a suspect after ante-mortem examination. (Courtesy of the Bureau of Animal Industry, U. S. Dept. of Agriculture, Washington, D. C.).

Immature animals, those in the advanced stages of pregnancy, or those which have recently given birth to young may be tentatively rejected and held until they become suitable for slaughter.

Passed as suspects. Animals having abnormal conditions or diseases which do not justify ante-mortem rejection, either outright or tentative, may be passed for slaughter as suspects

and final action taken in accordance with post-mortem findings.

The carcasses of animals passed as suspects should be inspected separately from other carcasses.

FIG. No. 105. Ante-mortem inspection of a retained suspect. (Courtesy of the Bureau of Animal Industry, U. S. Dept. of Agriculture, Washington, D. C.).

POST-MORTEM INSPECTION

A post-mortem inspection is an examination of the carcass or parts of a carcass, of a freshly slaughtered food animal for evidence of disease or other abnormal conditions which would render it unsuitable for food. Usually, the post-mortem inspection is made at the time of slaughter or immediately thereafter and, in order to avoid omissions and errors, it should be conducted in accordance with a predetermined routine. Usually an examination of the head, viscera, body and a secondary inspection of carcasses and parts of carcasses are made in sequence.

FIG. No. 106. Dressing floor in a large meat-packing establishment. (Courtesy of the Bureau of Animal Industry, U. S. Dept. of Agriculture, Washington, D. C.).

Conduct of post-mortem inspections. In order that the post-mortem inspection may be efficiently performed, suitable facilities and equipment must be provided. These include the necessary instruments, such as knives, sharpening steel, tenaculum, and magnifying glass, stamping outfit, inking pad, and indelible pencil, and facilities for disinfection of equipment and the hands (Fig. No. 107).

Measures to prevent the transmission of contamination from one carcass to another constitute an essential and important part of post-mortem inspection work. All instruments used in slaughtering and inspecting diseased animals should be properly disinfected. Measures should be taken by those handling the carcasses to prevent contamination of clean products by diseased carcasses or parts of carcasses or by the hands or clothing. Metal instruments may be disinfected by boiling in water containing one per cent of sodium carbonate. A good soap is satisfactory for use in disinfecting the hands. If an animal has anthrax, all parts of the carcass should be immediately burned, or converted into tankage, the killing bed disinfected with a 1:1000 mercuric chloride solution

and all contaminated instruments and utensils properly disinfected with boiling water or a suitable disinfectant.

The entire carcass may be rejected for food purposes or only a part may be rejected and the remainder passed as suitable for food. The entire carcass should be rejected if the post-mortem inspection reveals infection which is general or which has developed beyond a certain point as described be-

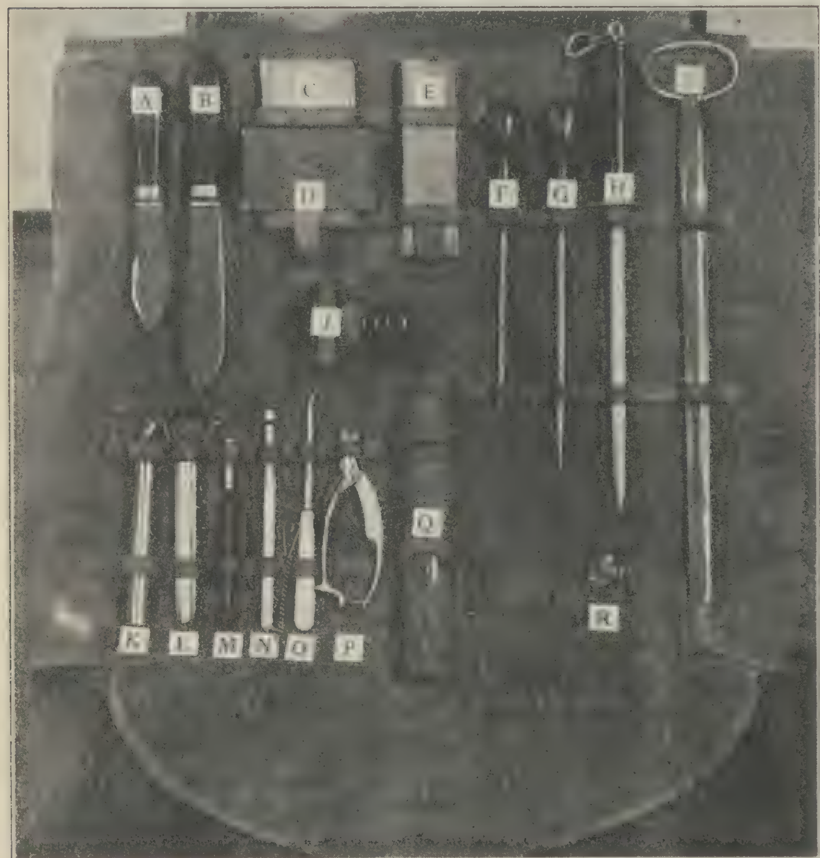


FIG. No. 107. Meat and dairy inspection case. (A) post-mortem knife (knife skinner, 4"); (B) post-mortem knife (knife skinner, 6"); (C) notebook; (D) inking pad; (E) sharpening stone (carborundum); (F) meat trier, 5"; (G) meat trier, 8"; (H) steel, 10"; (I) trier, lard and butter, 18"; (J) stamp, rubber, meat inspection; (K) marking ink container; (L) trier, cheese, 6"; (M) thermometer, clinical; (N) thermometer, dairy; (O) hook, gland, 8" (tenaculum); (P) can opener, "Deacon"; (Q) flashlight; (R) magnifying glass, pocket.

low, or the presence of disease or other conditions which affect all parts of the carcass. In other instances, the infected, contaminated or abnormal part may be rejected and the remainder of the carcass passed. Any part of a clean carcass which comes in contact with contaminated meat, either directly, or indirectly through the medium of contaminated instruments, implements, tables or containers, should be rejected.

FIG. No. 108. Post-mortem examination of viscera. (Courtesy of the Bureau of Animal Industry, U. S. Dept. of Agriculture, Washington, D. C.).

Outright rejection. Any carcass should be rejected outright if there is any evidence of infection which would, if transmitted to man, cause disease. A carcass showing any of the following conditions should be entirely rejected and no portion passed as suitable for food:

Anthrax.
Bang's disease.
Foot and mouth disease.
Splenetic fever.
Hemorrhagic septicemia.
Malignant epizootic catarrh.
Contagious pleuropneumonia.
Unhealed vaccine lesions.
Rinderpest.
Pyemia.
Septicemia.
Sapremia.
Toxemia.
Poisoning.
Parasitic icterohematuria (sheep.)
Hog cholera.
Swine plague.
Infestation with *Cysticercus cellulosae.*
Suffocation.
Hogs scalded alive.
Still born animals or fetuses.

A carcass should be rejected outright when any of the following diseases are present in a *generalized* form:

Actinomycosis.
Caseous lymphadenitis.
Tuberculosis.
Infestation with *Cysticercus bovis.*
Infestation with *Cysticercus ovis.*
Other parasitic infestations.
Melanosis.
Pseudoleukemia.
Carcinomatosis.
Sarcomatosis.
Necrobacillosis.
Paratuberculosis.

Carcasses should be completely rejected if the flesh is extensively bruised or damaged. Complete rejection should also be made if there is evidence that death was due to any cause other than slaughter. If an odor of urine or a sexual odor develops after chilling, as shown by a heat test, the carcass should be condemned.

No carcass should be passed as suitable for food unless the animal has been passed at an official ante-mortem inspection. An exception to this ruling is sometimes made when the animal is known to have been slaughtered on a farm and the head and all the viscera are available for post-mortem inspection.

Partial rejection. A part of a carcass may be rejected and the remainder passed as suitable for food if the character of the lesions or defects is such that the passed portion will not be dangerous to health.

Tuberculosis. If lesions of tuberculosis are found at post-mortem inspection, the uninvolved portion of the carcass may be passed for food if the lesions are localized and the animal is well nourished, provided there is no evidence of generalized tuber-

FIG. No. 109. Post-mortem examination of hog carcasses. (Courtesy of the Bureau of Animal Industry, U. S. Dept. of Agriculture, Washington, D. C.).

culosis and the parts containing the lesions are removed and condemned. Tuberculosis is considered to be localized when only slight, encapsulated or calcified lesions are to be found which are few in number and limited in distribution.

About 0.4 per cent of all beef carcasses examined are condemned because of tuberculosis. Approximately 12 per cent of all hog carcasses show evidence of tuberculosis, and about 2 per cent of all hog carcasses are condemned because of tuberculosis. Much of the tuberculosis found in swine is the avian type, which is rarely transmitted to man.

Actinomycosis. Carcasses with uncomplicated, localized lesions of actinomycosis may be passed for food if there is no evidence of generalized actinomycosis, and the parts involved are removed and condemned.

Cysticercus bovis. If not more than one dead and degenerated cyst of *Cysticercus bovis* is found, the carcass may be passed for food after the removal of the cyst.

Cysticercus ovis. A carcass which is infested with *Cysticercus ovis* may be passed for food if not more than five cysts are found, and the infested portions are removed and condemned.

Caseous lymphadenitis. If lesions of caseous lymphadenitis are found, the carcass may be passed for food purposes only if the animal is well nourished and the lesions are limited to the viscera or the skeletal lymph glands with only slight lesions elsewhere.

INSPECTION OF MEAT PRODUCTS

Meat products include all food supplies consisting of, or containing the flesh of food animals, such as fresh meat, chilled or frozen meat, or meat which has been processed, cured, canned, rendered, or otherwise prepared or preserved. The inspection of meat products which are to be consumed by troops includes investigation, and at times supervision, of the sanitary conditions under which the product is prepared, handled, transported, stored or issued.

Usually, the inspection of meat products by army inspectors is restricted to reinspection and may be made prior to purchase, in storage, after purchase, on receipt by issuing agencies, or at the time of issue at messes and kitchens. This inspection is ordinarily concerned only with the nutritive and sanitary quality

FIG. No. 110. Final examination of a retained carcass. (Courtesy of the Bureau of Animal Industry, U. S. Dept. of Agriculture, Washington, D. C.).

of the product, but meat products are occasionally inspected solely for the purpose of determining wholesomeness and conformity with purchase specifications. Veterinary inspections include supervision of manufacturing of meat products for army use.

The products inspection is not a substitute for ante-mortem and post-mortem inspection. Conditions can be detected by ante-

mortem and post-mortem inspections which would give no evidence of their presence in the finished product. Assuming that all prior inspections have shown the product to be acceptable, the products inspection is made to determine if changes or deterioration have impaired the quality of the product or rendered it unsuitable for issue to troops. The products inspection is, therefore, the immediate and final safeguard against the consumption of contaminated or dangerous meat products.

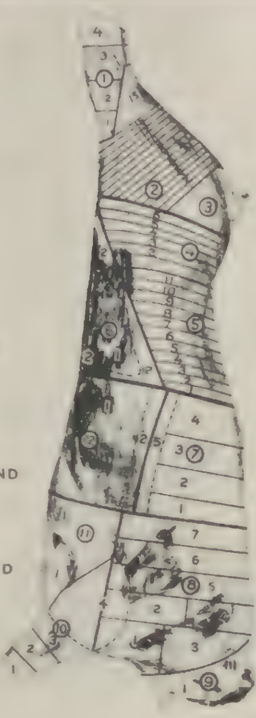
INSPECTION OF FRESH MEATS

Fresh meats include beef, veal, mutton, lamb and pork, which may be frozen, chilled, or unchilled. The inspection of fresh meat is a piece inspection and is made prior to purchase, on receipt and on issue. Inspection of fresh meat in storage prior to issue, or after issue to organizations, may also be required.

Grading of fresh meat. *Carcass meat.* The carcass of a food animal consists, generally, of the dressed body from which the offal has been removed and includes the two sides of the body, less the head and lower portions of the legs. The hog carcass may include the head and feet. The carcass may be divided into fore quarters and hind quarters, or other standard cuts. Special trimming or cuts may be required by army specifications and the inspector should be familiar with the specifications under which the meat has been or is to be purchased (Figures No. 111, 112, 113 and 114).

Offal. The offal consists of edible and inedible products, and tissues to be employed in the manufacture of pharmaceutical products derived from slaughtered food animals. It includes the blood, hide, viscera, legs and head. The edible offal, such as liver or brains, is subjected to the same inspections as carcass meat.

System of grading. The carcass meat of different food animals is separated by trade and inspection practices into grades which are determined by various factors pertaining to the quality and appearance of the product. Fundamentally, the grading of carcass meat is based on quality, finish and conformation, together, in some instances, with age, sex, weight and many other minor factors which determine the quality and finish. The *soundness* of meat governs its sanitary, and, to some extent, its nutritive quality, and from the viewpoint of health protection is the most important factor to be determined by products inspec-



(1) HIND SHANK
1 TO 3 SOUP BONES
4 - HOCK

2 ROUND
1 TO 14 ROUND STEAKS
15 HEEL OF ROUND

3 RUMP
STEAKS OR ROASTS

4 LOIN END
1 TO 6 SIRLOIN STEAKS

5 SHORT LOIN
1 TO 3 CLUB OR DELMONICO STEAKS
4 TO 11 PORTERHOUSE STEAKS

6 FLANK
1 - FLANK STEAK
2 - STEWS OR HAMBURGER

7 RIB
1 TO 4 RIB ROASTS
5 SHORT RIBS

8 TRIMMED CHUCK
1 & 2 BOTTOM CHUCK ROASTS
3 & 4 TOP CHUCK ROASTS
5 TO 7 CHUCK RIB ROASTS

9 NECK
1 - BONELESS ROASTS
STEWS OR HAMBURGER

10 FORE SHANK
1 TO 3 SOUP BONES
4 - SHOULDER CLOD

11 BRISKET
1 - STEWS OR BONED AND ROLLED ROASTS

12 PLATE
1 - STEWS OR BONED AND ROLLED ROASTS
2 - SHORT RIBS

Numerals in circles ◯ refer to wholesale cuts and major subdivisions of such cuts. Other numerals refer to retail cuts

WHOLESALE CUTS AND SUBDIVISIONS
ALL PERCENTAGES BASED ON CARCASS WEIGHT

(1) TO (6) HINDQUARTER	48.0%	(7) TO (12) FOREQUARTER	52.0%
(1) TO (3) ROUND AND RUMP	24.0	7 RIB	9.5
(1) HIND SHANK 4.0%		(8) & (9) CHUCK	22.0
(2) BUTTOCK 15.0		(8) TRIMMED CHUCK 17.0%	
(3) RUMP 5.0		9 NECK 5.0	
(4) & (5) FULL LOIN INC. SUET	20.5	(10) FORE SHANK	5.5
(4) LOIN END 7.0		(11) BRISKET	6.5
(5) SHORT LOIN 10.5		(12) PLATE	8.5
KIDNEY KNOB 3.0			
(6) FLANK	3.5		

FIG. No. 111. Wholesale and retail cuts (beef). (Courtesy of the Bureau of Agricultural Economics, U. S. Dept. of Agriculture, Washington, D. C.).

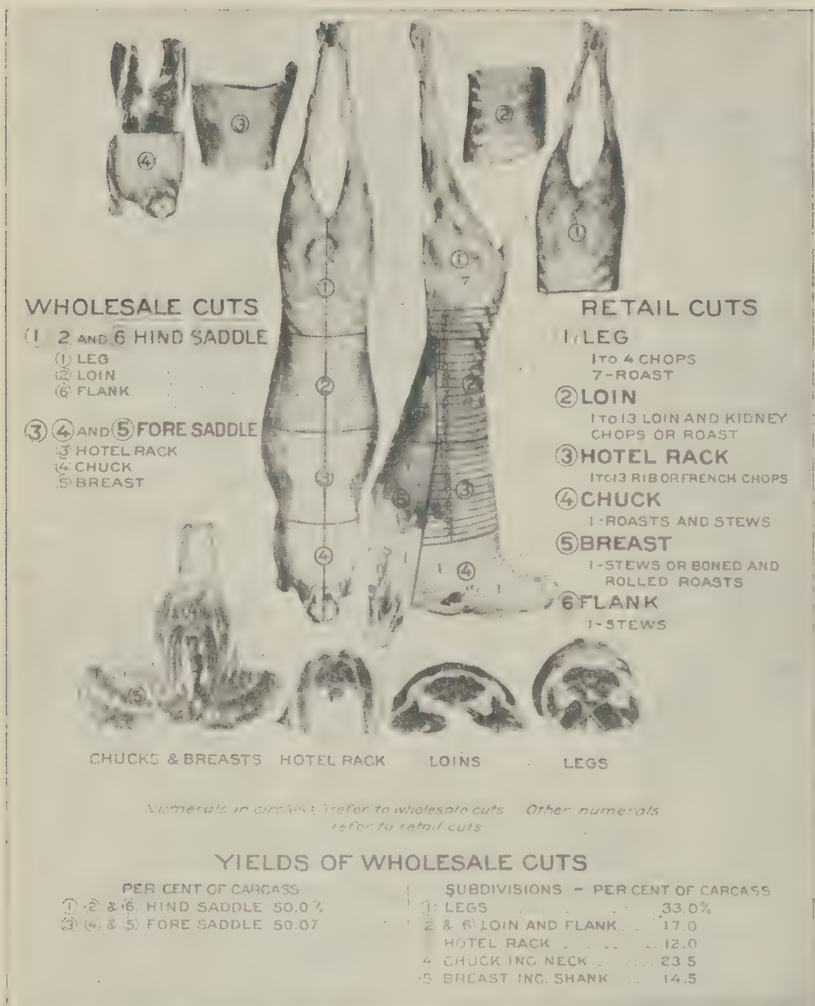


FIG. No. 112. Wholesale and retail cuts (lamb). (Courtesy of the Bureau of Agricultural Economics, U. S. Dept. of Agriculture, Washington, D. C.).

tion. The other attributes of fresh meat, such as finish and conformation, determine the grades required for commercial reasons and, in some instances, indicate in general the nutritive value and desirability of the product as an article of food. They are very important in so far as purchase specifications are concerned, but do not affect the soundness of the meat.

WHOLESALE CUTS - PERCENTAGE OF CARCASS

1-HIND FEET	1.00%	7-BRISKET	2.25%	12-JOWLBUTTS (TRIMMED)	2.25%
2-HAMS	19.00	8-PICNIC	7.50	13-BONELESS BUTT	3.05
3-CLEAR BELLIES	16.50	9-N.Y. STYLE SHOULDER	16.00	13-BOSTON BUTT	5.20
4-PORK LOINS	12.75	10-NECK BONES	.95	14-LOIN BUTT	4.00
5-SPARE RIBS (F.S.)	2.50	11-PICNIC BUTT	3.02	15 FORE FEET	.92
6-SPARE RIBS (H.S.)	1.50	12-JOWL BUTTS (UNTRIMMED)	3.75	16 LEAF FAT	3 52

FIG. No. 113. Wholesale and retail cuts (pork). (Courtesy of the Bureau of Agricultural Economics, U. S. Dept. of Agriculture, Washington, D. C.).

Soundness of fresh meat. Meat is considered to be unsound which has deteriorated or undergone any undesirable changes subsequent to post-mortem inspection, or which shows evidence of bruising, inadequate bleeding, mutilation, fibrillar muscular ruptures, decomposition, or any other condition which would render it unwholesome as food. Any meat which has not been passed as suitable for food at ante-mortem and post-mortem inspections performed by acceptable inspection agencies, or has not been of-

ficially stamped as passed by such agencies, is also classed as unsound meat. Unsound meat should always be rejected for use by the troops.

Bacterial decomposition of fresh meat. The meat of a healthy animal is free from bacteria and all bacterial decomposition is due to contamination subsequent to slaughter. It is not practicable, however, to prevent a certain amount of contamination during the handling of meat so that all fresh meat is more or less contaminated with bacteria and fungi. Where the meat is properly handled, the contaminating organisms are non-pathogenic, but they may cause spoilage of the meat. Under insanitary conditions, the meat may be contaminated with pathogenic organisms.

Bacteria and fungi are always to be found on the surfaces of freshly slaughtered meat. These organisms are derived from the air, hands and clothing of the workers, and various other sources which cannot be avoided during the preparation of the meat. At this time the interior of the meat is normally free from bacteria. Organisms may be carried into the tissues by contaminated instruments during the dressing of the carcass, or their penetration may be facilitated by delay in the removal of the viscera, inadequate chilling, by fatigue at the time of slaughter or, in the case of hogs, by prolonged exposure in the scalding vat. Excessive surface contamination may also be a factor in promoting the rapid penetration of organisms into the interior of the meat.

Usually the bacteria grow and spread over the surface and by colony extension slowly penetrate the outer layer of the meat. The dryness and hardness of the surface determine to a considerable degree the rate of penetration. In meat which has been thoroughly dried and then hardened by chilling, the bacteria grow slowly and penetration is delayed. Conversely, a moist and relatively soft surface is conducive to rapid bacterial growth and penetration. Under these conditions, particularly if the air is moist, a layer of slime, consisting of bacteria and fungi, forms on the surface of the meat and bacterial penetration into the meat, with consequent spoilage, is accentuated.

Given average conditions with regard to surface dryness and hardness, the bacteria on the surface of meat in chill room storage will penetrate to a depth of about one-half inch in 30 days. If the meat is cut, the depth of penetration will be shown by a dark, well defined border extending completely around the cut.

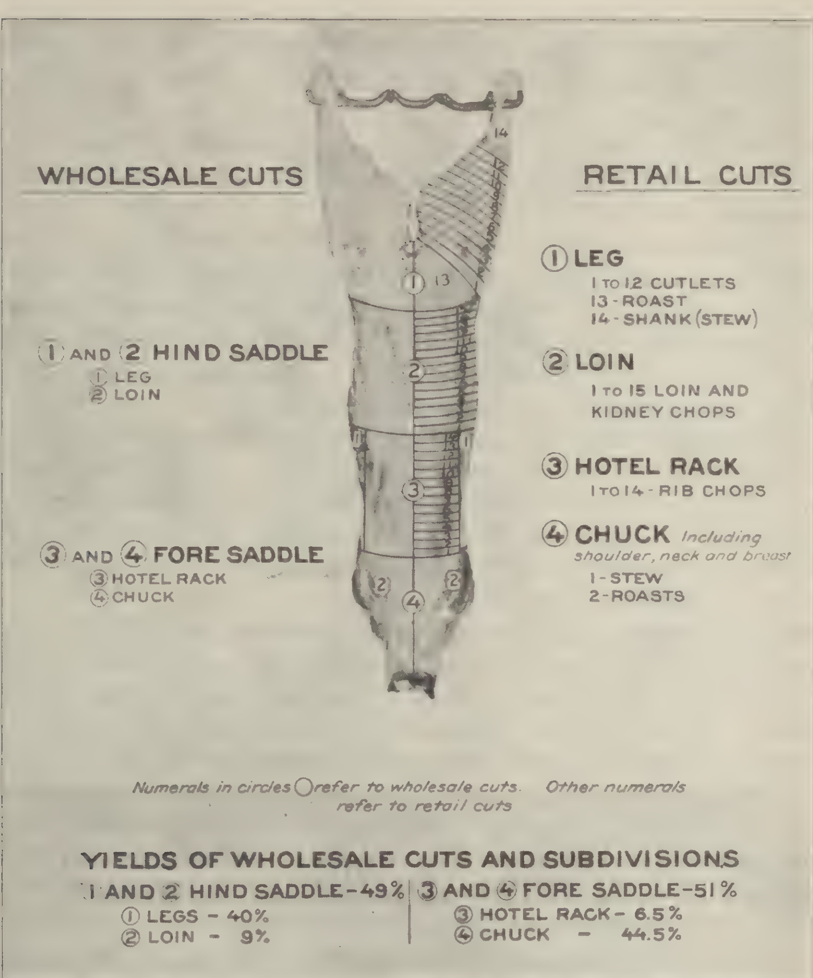


FIG. No. 114. Wholesale and retail cuts (veal). (Courtesy of the Bureau of Agricultural Economics, U. S. Dept. of Agriculture, Washington, D. C.).

Bacteria may penetrate rapidly and deeply into the tissues by growth along moist surfaces between muscular tissues or through open vessels. Such growth may cause areas of decomposition in the deep parts of the tissues and around the bones without involvement of the surface.

The bacterial decomposition of meat is prevented or delayed by adequate ante-mortem and post-mortem inspections, by the sanitation of establishments, by refrigeration and by curing and

canning processes. Ante-mortem inspections prevent the slaughter of infected animals, or those that are fatigued, overheated, emaciated, or in such other condition that bacterial invasion of the tissues occurs prior to or at the time of slaughter. Post-mortem inspections and the sanitary supervision of establishments minimize or prevent contamination of the meat after slaughter.

Refrigeration of fresh meat. All fresh meat must be chilled to remove the animal heat. Chilling may be followed by sale or issue for consumption, or chilled meat may be frozen preparatory to prolonged storage or shipment. Improper chilling, whether due to delay or faulty methods, promotes bacterial decomposition and rapid spoilage.

Small quantities of meat may be chilled in ice boxes, but slaughtering establishments are usually equipped with cold storage plants in which brine or ammonia is used as a refrigerant. In a cold storage plant, the rooms in which meat is chilled are known as chill rooms or coolers. The rooms used for freezing meat are called freezers.

All refrigerating systems should be so installed and operated, and all cold storage rooms should be so constructed and insulated, that the desired temperature can be uniformly maintained. A ventilation system with adequate air circulation is necessary to carry away steam, moisture and odors.

Usually the initial heat is removed in one cooler, known as *fore*, *warm* or *hot* cooler, and final chilling and storage are accomplished in a second or main cooler. If warm and chilled carcasses are placed in the same chill room, moisture will condense on the chilled meat and produce slime.

The freshly dressed carcasses or sides are hung in the fore cooler in such a way that they are separated by space sufficient to insure ample air circulation. Carcasses are held in the fore cooler for a period of from 18 to 24 hours at a temperature of from 34°F. to 38°F. and then transferred to the second or main cooler where they usually remain for an additional 48 hours at a temperature of from 32°F. to 34°F.

Light beef carcasses may be removed from the chill rooms after 36 hours, but the heavy sides should remain from 48 to 72 hours.

Firm, well finished beef may be stored in chill rooms under proper conditions for 30 days or longer without marked deteriora-

tion. Thin carcasses that do not become firm on chilling tend to deteriorate much more rapidly and should not be retained in chill rooms for any considerable number of days beyond the end of the chilling period.

Chilled fresh pork tends to deteriorate more quickly than other meat products under similar conditions. Properly chilled pork carcasses will remain free from serious deterioration for from 8 to 10 days, but pork cuts should be frozen, rather than chilled, if they are to be stored for longer than four or five days.

Meats may be preserved by freezing for practically an indefinite period of time. Frozen meat can be held in storage until required for consumption, or it can be shipped for long distances without the occurrence of spoilage. Sound and thoroughly chilled meats are frozen in freezers in which the temperature is from 10° below to 10° above zero F. After freezing, the meat is stored at temperatures ranging from zero F. to 10°F.

Defrosting of frozen meat. Frozen meat which is not properly thawed or defrosted tends to undergo rapid bacterial decomposition. Frozen meat should be defrosted by storage for about four days in a well ventilated cooler at a temperature of about 38°F. In an emergency, when rapid defrosting is necessary, the meat may be thawed by storage at a temperature of about 70°F. Whenever practicable, the slower method should be used. Meat which has been thawed in water is particularly apt to spoil rapidly.

Storage of meat at stations or camps. After receipt at stations or camps, fresh meat may be stored in the refrigerator car in which it was shipped, in the chill rooms of a cold storage plant, or in the ice boxes of butcher shops or organization kitchens. The keeping qualities of the meat after receipt depend to a considerable extent on whether or not the meat was properly chilled and handled prior to receipt. Meat removed from refrigerator cars and stored immediately in chill rooms at a temperature of about 35°F. will usually remain free from decomposition for from 6 to 10 days. If meat which is received in refrigerator cars is stored in refrigerators or in ice boxes, at the usual temperature of from 45°F. to 55°F., it will probably present evidence of decomposition and become unsuitable for food after about 72 hours. Meat purchased from local establishments should not be held in the refrigerator

or ice box of the local kitchen for more than 24 hours prior to cooking.

When fresh meat is stored in the refrigerator in the mess it should be hung from hooks in such a manner that there is sufficient air space between the pieces, and between the meat and the walls, ceiling or floor of the box. In the absence of air circulation, the meat tends to become moist and slimy and undergo decomposition where the surface is in contact with any other object.

Local inspection of fresh meat. Local sanitary inspections of fresh meat are usually made prior to purchase, on receipt of purchased supplies, at time of issue to the troops, and in the kitchens of the using organizations. These inspections are most important, as their ultimate objective is to determine that the condition of the meat at the time of its preparation for consumption is or will be such that it will not be detrimental to the health of the consumer.

As a health protective measure, all fresh meat which is to be consumed by troops should be inspected by a medical department officer at the time of or subsequent to its receipt at the station or camp and within 24 hours of the time it is to be served as food. At the larger stations or camps, particularly if there are a number of organization kitchens, all deliveries of fresh meats or other meat products, whether purchased locally or otherwise obtained, should be made at a selected point so that the final inspection of the entire supply for the station or camp can be made at one place and at one time. If this is not practicable, the meat should be inspected at the organization kitchens.

Decomposition subsequent to a post-mortem inspection is caused by improper storage or handling and the consequent growth of bacteria on or in the meat. The meat may become infested with insect larvae or it may be damaged by rough handling. Occasionally, defects which impair the soundness of the product will be overlooked at the post-mortem inspection and these should be sought on subsequent reinspections.

The inspection of fresh meat is made principally by direct observation. If the meat is wrapped, the wrappings should be removed sufficiently to permit inspection of all parts and surfaces. Good, high grade meat is dry, firm to the touch, of normal color and free from abnormal odors. A wet, slimy or

mouldy surface is indicative of beginning surface spoilage and is due to poor storage conditions or prolonged cooler storage. Slime is to be found most frequently on the peritoneal and pleural surfaces or where two surfaces are in apposition. Softened areas usually indicate unsoundness due to improper cooling and consequent decomposition.

The color of choice fresh meat should be as follows:

Beef	Bright red.
Veal	Pinkish brown.
Mutton	Dark pink or red.
Lamb	Light pink.
Pork	Light pink.

Abnormally dark colors are caused by advanced age, overheating or disease at time of slaughter, improper bleeding, prolonged storage in chill rooms, or exposure of the meat to warm air after removal from the chilling room or after defrosting. Abnormally pale colors are usually evidence of immaturity. Sour, putrid, or other abnormal or "off" odors are indicative of spoilage.

Decomposition of the deep tissues most frequently occurs in the vicinity of the large joints or long bones. Any evidence of improper chilling, such as wrinkled or slimy surfaces, may be indicative of decomposition of the deep tissues. Where such decomposition is suspected, a meat trier should be passed down to the bone or joint, or an incision made with a knife. If decomposition is present, the characteristic odor of putrefaction or souring will be given off from the trier, or from the meat if an incision is made.

The inspection should include a search for evidence of bruising, or the removal of bruises by excision, and all meat should be carefully examined for parasites and for fibrillar muscular rupture.

The inspection of fresh meat also includes, where applicable, consideration of all evidence of prior inspection, such as stamps, tags or other markings and the sanitary conditions under which the meat has been, or is being, stored or handled.

Properly frozen meat is hard and firm and the surface is dry. If partial thawing has occurred, the surface will be soft and moist. Where frozen meat shows evidence of thawing, the condition of the deep tissues may be tested by means of a wood auger, which, if the meat is well frozen, will cut a

clean hole, but will not cut through meat which is not completely frozen.

If decomposition occurred in the deeper tissues before the meat was frozen, it will not usually be detected by the ordinary inspection of the frozen product. If decomposition is suspected, or the nature of the inspection renders it desirable, a specimen of the meat should be obtained with an auger from the tissues adjacent to the long bones or large joints and subjected to the ammonia test (Eber Test). The specimen should be defrosted and warmed to room temperature before testing.

The ammonia test for decomposition of fresh meat is based on the reaction of the free ammonia resulting from decomposition with the fumes of hydrochloric acid and the formation of white fumes of ammonium chloride. The reagent consists of a mixture of one part of concentrated hydrochloric acid, one part of ether and three parts of absolute alcohol. The reagent should be kept in a tightly stoppered glass bottle.

The test is made by placing about 2 c.c. of the reagent in a clean test tube and shaking. A small piece of the meat to be tested is lowered into the test tube by means of small forceps, a glass rod or a tenaculum to within about one-fourth inch of the surface of the reagent. If ammonia is present, the white ammonium chloride fumes will appear around the specimen.

A small auger shaving of the frozen meat may be thawed by rubbing between the hands and examined for abnormal odors indicative of spoilage. Boiling a small piece of the meat will, in some instances, result in the development of a characteristic odor if decomposition is present.

Results of inspection. Meat which is not known to have been subjected to a satisfactory ante-mortem inspection and which is not stamped as officially passed by post-mortem inspection is potentially dangerous to the health of the troops because of the absence of these safeguards. Such meat may present a satisfactory appearance on inspection but must, nevertheless, be rejected for issue to the troops.

If an army inspector finds that a carcass or cut shows evidence of unsoundness he should recommend that it be partially or totally rejected for food purposes. Outright rejection should be recommended if the unsoundness involves any considerable proportion of the carcass or cut. In all questionable cases, rejection of the entire piece should be recommended.

Partial rejection may be satisfactory where the decomposed area is relatively small or where decomposition consists entirely of surface slime. If the decomposed areas can be entirely removed by trimming, the unaffected portions may be passed as suitable for food. Frequently, the surface growth of bacteria, as manifested by slime or mould, has not penetrated into the meat. The slime or mould should be removed by wiping and if the tissues are found to be sound, the meat can be safely used as food. All meat that is trimmed or wiped, or otherwise treated, should be reinspected thereafter to determine if the retained portions are sound and suitable for food. However, such partial rejection, with the elimination of unsound portions by trimming or removal of slime or mould by wiping, should be recommended only when the meat is in the possession of the quartermaster or the using organization. If the inspection is made prior to purchase, total rejection of all meat showing unsoundness in any degree should be recommended.

INSPECTION OF CURED MEAT PRODUCTS

Cured meat is meat preserved with chemicals or by drying, and includes salted, smoked, pickled and dried meat. All cured meats should be free from unsoundness prior to curing and should be cured, handled or stored under sanitary conditions. Establishment inspections should be made in the same manner as in the case of fresh meat and procedures utilized in curing the meat should be subject to constant inspection and sanitary supervision by the appropriate inspection agencies. The necessary reinspections should be made as required.

Storage. Cured meat should be stored in dry, well ventilated storerooms at a temperature of between 40°F. and 50°F. Good air circulation and freedom from dampness are essential in order to prevent the formation of mould or slime. Each piece should hang free from contact with another piece or with the wall of the room. If crated, the crates should be stored so as to permit the circulation of air around each crate.

The keeping qualities of smoked meat depend, to a considerable extent, on the methods of curing and the storage conditions. Under good conditions, smoked meat may be stored without damage for from 30 to 60 days. Sugar cured

ham and breakfast bacon should not be kept in storage for more than 30 days. Army bacon may be kept for a longer period. Properly stored salt meats will keep for relatively long periods of time.

Methods of inspecting. Cured meat products are, as a rule, reinspected by army inspectors prior to purchase or at time of receipt, at issue, and in the kitchens of the using organizations. These inspections are essentially examinations for soundness of the cured product, but also include, when pertinent, sanitary inspection of the methods of storing and handling the meat.

Usually, if a considerable quantity of meat is to be inspected, about 10 per cent of the pieces are examined. If unsound meat is found, each piece in the lot should be carefully inspected. The inspection includes an examination for bruises, mutilation of any kind, discoloration, soft white spots, slime, mould, infestation with insect larvae, sourness, rancidity, or other indications of decomposition, or evidence that the meat has been trimmed to remove unsound portions.

In smoked meat, if decomposition is present it will frequently be found in the bone marrow or in the tissues adjacent to the bones and joints in otherwise sound products. Occasionally, decomposition also occurs in the deep tissues of hams. In bacon, small areas may undergo decomposition. The deep tissues of smoked meat should be examined by inserting a trier into the body of the piece in the vicinity of the rib attachments and string holes, and along and into the bones or joints. Upon withdrawal, the trier is examined for any abnormal odor indicative of spoilage (Fig. No. 115).

The surface should be examined for soft, white or uncolored areas caused by contact between the pieces during the smoking process or faulty handling prior to smoking. The wrappings should be inspected for tears or holes which would admit dirt or insects.

The storage conditions should be determined with particular reference to air circulation, moisture and temperature.

Results of inspection. All cured meats which do not bear a stamp showing that they have been subjected to prior official inspections should be rejected for purchase. If in the possession of the government, they should be subjected to a strict

FIG. No. 115. Inspection of cured hams, using a trier to detect odor of decomposition in interior of ham. (Courtesy of the Bureau of Animal Industry, U. S. Dept. of Agriculture, Washington, D. C.).

100 per cent piece examination, and passed for food purposes only if found to be unquestionably free from defects.

Cured meats showing any evidence of decomposition of the deep tissues should be rejected unless the area involved is very small and can be trimmed out without detriment to the

remainder of the piece. Meat infested with insect larvae should ordinarily be considered as unsuitable for food. Occasionally, in slightly infested meat, all the larvae can be removed by trimming, but the trimming must be very carefully done and the meat must be again inspected after trimming.

Mould and slime, if not too extensive, can be removed by wiping with a cloth or by washing the surface of the meat with a dilute solution of vinegar in water. If the subsurface tissues are involved in any way, the meat should be rejected.

Mutilated or torn meat, or meat showing white areas due to improper smoking, should be rejected for purchase. If inspected subsequent to purchase, it should be very carefully examined, as such defects tend to promote rapid spoilage.

INSPECTION OF CANNED MEATS

Canned meats are meat products which are preserved in hermetically sealed metal or glass containers. The principal kinds of canned meats issued to troops are corned beef, fresh roast beef, sliced dried beef, bacon, pork and beans, deviled ham, sausage, veal loaf and meat soups.

With the exception of bacon and dried beef, the contents of the can are sterilized by heat subsequent to sealing and are maintained in a sterile condition thereafter until the can is opened. Bacon and dried beef are canned without sterilization and for the purpose of affording protection from contamination.

Methods of inspection. The meat intended for canning should be subjected to the same kind of ante-mortem, post-mortem and establishment inspections as other meats. The canning process should be conducted under the official supervision of civilian or military inspection agencies.

Deterioration of the canned product is caused by faulty canning methods and by any defect in the can which will admit air and contamination. Spoilage or damage is indicated by evidence of defective cans or of decomposition of the contents of the can.

Canned meats should be inspected for deterioration on receipt, at issue, and in the kitchens of the using organizations. The inspection is made by examination of the unopened can and of the contents of suspected or selected cans.

An acceptable can should be firm and tight and free from loose tin, dents, or rust. If the contents of a can are sound, the ends of round cans and sides of square or flat cans are concave, due to the vacuum created during the canning process. Insufficient vacuum or loss of vacuum, with consequent flattening or bulging of the ends or sides, is due to defects which permit air to enter the can or to decomposition of the contents with gas formation.

Defective cans are classified according to the nature of the defect as leakers, swellers, or springers.

Leakers. A leaker is a can presenting a defect through which air may enter or the contents escape. Leakage is usually due to defects or perforations which develop during the manufacture of the can, or are caused by damage incurred during the canning process or by handling and transportation subsequent to canning. Where the perforations are small, leakage may be indicated only by the removal of the vacuum and the consequent disappearance of the concavity in the ends or the sides of the can. More extensive leakage is usually evidenced by a visible aperture or the escape of the contents of the can.

The amount of vacuum may be determined by tapping the can with a piece of wood or a tapping instrument. If the vacuum is adequate, a dull sound will be elicited while a hollow sound denotes the complete or partial replacement of the vacuum by gas or air. Overstuffed cans or cans containing a considerable amount of liquid may yield a dull note on percussion, even though no vacuum is present.

In some instances, a leaking can may be detected by compression under water which will, if a relatively large aperture is present, force air bubbles from the can. A suspected leaker may be slowly heated to about 100°F. and then allowed to cool. If a leak is present, the concavity of the ends or sides will disappear. A leaker may become a sweller or a springer (*infra*).

Swellers. A sweller is a can which contains gas in sufficient quantities to produce bulging or distension of the sides or ends. The gas may be and usually is due to contamination with gas producing organisms resulting from incomplete sterilization, or contamination subsequent to sterilization. Occasionally, chemical changes may cause the formation of gas,

or air may leak into the can through a perforation. In the latter case, the can is a leaker as well as a sweller.

Usually, a sweller may be detected by the appearance of the can. Where no bulging or distension is evident, the presence of gas or air in quantities which are insufficient to destroy the vacuum completely may be demonstrated by the sound produced by tapping the can.

Springers. A springer differs from a sweller only in that the accumulation of gas within the can is not sufficient to eliminate entirely the negative pressure. Usually, the reduction in the internal negative pressure is such that the normal concavity disappears from one end or side. When the flattened or convex end or side is rendered concave by external pressure, the other end or side springs outward to become flat or convex. A springer results from the same causes as a sweller and may also be due to incomplete exhaustion of the air at the time the can is sealed. The continued formation of gas within a springer will convert it into a sweller.

Inspection of can contents. The can should be opened in such a manner as to avoid damage to the contents. The contents should be carefully examined for abnormal odor, appearance or taste indicative of decomposition. The inside surface of the can and the contents should be inspected for the presence of black discolorations due to chemical reaction between the contents and the metal.

Laboratory examinations of canned meats may be made to determine the presence of adulteration or preservatives, or the nature of bacterial contamination. Such examinations are performed in Medical Department laboratories.

Results of inspection. If canned meats are inspected prior to purchase or prior to the expiration of a seller's guarantee, all cans which are defective or damaged, as well as those the contents of which show evidence of deterioration, should be rejected. When inspected at issue or in the kitchens of using organizations, the contents of any can showing evidence of decomposition should be rejected as unsuitable for food. As the cans are at this time in possession of the Government, the contents of dented, rusted or otherwise damaged cans may be passed for food if there is no evidence of spoilage. All leakers, swellers and springers should be invariably rejected.

Any abnormal odor or appearance should be considered as indicative of decomposition and as a cause for condemnation.

Usually, canned meats for army use are procured from packing houses engaged in interstate trade and are, therefore, subject to inspection by federal agencies. In many instances, such products are prepared under the supervision of a veterinary officer. If canned meats are purchased from local establishments, they should be prepared under supervision of military or acceptable civilian inspection agencies. If evidence of such supervision is lacking, the products in question should be rejected for purchase or issue.

MISCELLANEOUS MEAT PRODUCTS

Miscellaneous meat products include all those which are not classed as fresh, cured or canned meats. The animal fats and sausage are the most important of the miscellaneous meat products that are issued to troops.

Rendered animal fats. The principal rendered animal fats of an edible nature are those derived from beef, pork and mutton. Beef fats are rendered into oleo stock and edible tallow. Oleo oil and oleo stearine are obtained from oleo stock. Oleo oil is used in the production of animal margarine. Oleo stearine is used in the manufacture of candy, margarine and lard substitutes. Edible tallow is employed in the manufacture of lard substitutes, lard compounds, margarine and for baking purposes. Pork fats are rendered into lard or enter into the production of lard compounds, lard stearine, lard oil and margarine.

Lard, lard compounds, and lard substitutes. The pork fats from which lard is obtained are classified, generally, as leaf, cutting, killing or butcher, and cured fats. Leaf fats constitute the best grade and are obtained from the retroperitoneal layer of fat. Cutting fats are obtained from the ham, shoulder, back and other cuts and are inferior to leaf fats but will, if properly handled, yield a good grade of lard. Killing fat is the fat which is removed from the carcass during the dressing process and from the offal. It produces a dark colored lard which may have an abnormal odor. Cured fats are obtained from cured pork. Lard made from cured fats

is dark in color and usually has a flavor corresponding to the kind of cure used.

The various grades of lard as purchased for army use are classified as kettle rendered and steam rendered.

Kettle rendered lard. Kettle rendered lard is rendered in open or closed kettles which are heated by steam or fire. The fat does not come in contact with steam and is not under pressure while being rendered. Kettle rendered lard is made from leaf fat alone or leaf fat and cutting fat. The No. 1 dry neutral grade is made from leaf fat and the No. 2 dry neutral grade from leaf and back fats or from back fats alone.

Steam rendered lard. Steam rendered lard is lard that is rendered in tanks by the direct application of steam under pressure. All edible hog fat may be used in the production of steam lard, but the better grades, as represented by prime steam lard, are made from approximately 60 per cent of cutting fats and 40 per cent of killing fats.

Prime steam lard is not bleached, filtered or otherwise refined. It has a coarse grain and characteristic flavor due to the method of cooking.

Refined lard. Refined lard is produced from prime steam lard by agitation, filtering, bleaching and chilling. It is smoother and more homogeneous than prime steam lard and has a better flavor.

Lard compounds. Lard compound is made by combining lard with other fats such as vegetable oil, lard stearine, oleo stearine or tallow. An acceptable product should contain at least 50 per cent of lard.

Lard substitutes. Various mixtures of vegetable oils, or animal fats and vegetable oils, are compounded to form substitutes for lard. Deodorized coconut, cottonseed, corn, soya or peanut oils may be used, either alone or in combination with lard, oleo stearine or tallow. The animal fats are used to stiffen the product and raise the melting point.

Lard substitutes should be so made that they will remain solid at a temperature of 70°F. Army purchase specifications usually require that lard substitutes shall consist of deodorized vegetable oils alone or combined with not more than 20 per cent of prime oleo stearine, and that they shall be free from rancidity, sourness or foreign odor, and added water.

Storage. Lard is packed for shipment or storage in tierces, cartons, pails, boxes, barrels, tubs, kegs or drums. Lard destined for use in the tropics, or for export generally, may be made more firm by the incorporation of hydrogenated lard or lard stearine.

Lard should be stored in a dry place at a temperature of not more than 36 F. Lard substitutes do not keep as well as refined lard and should not be stored for longer than from 30 to 60 days. Refined lard, when stored at a temperature of not more than 36 F., should remain in good condition for at least a year. Unsound fats and contamination of the rendered product will impair the keeping qualities of the finished article. Lard containing moisture tends to become rancid or sour. Relatively high storage temperatures promote the production of rancidity and sourness, especially if the lard is old or becomes soft.

Inspection of lards. The production of lard should be supervised by official inspection agencies in the same manner as other meat products, including ante-mortem and post-mortem inspections. The finished product may be reinspected prior to purchase, on receipt, in storage, at the time of issue or in the kitchens of the using organization.

On reinspection at any time, the lard should be white and free from discolorations, or abnormal odors or flavors. In texture, it should be smooth and firm. Samples should be obtained by inserting a trier down to the bottom of the container, as rancidity, sourness or other decomposition may be more pronounced near the bottom where the moisture tends to collect. Souring may be due to the presence of tank water which has soured or undergone decomposition. Abnormal odors may be more easily detected if a sample of the lard is heated, or warmed by rubbing between the fingers or palms.

Laboratory examinations of lard samples are made at Medical Department laboratories. A trier sample should be placed in a glass, tin or other nonabsorbent container having a tight lid so that no moisture will be lost during transportation to the laboratory. The sample must not be wrapped in paper. At the laboratory, examinations are made for adulterations, the presence of free fatty acids, and to determine the iodine number, together with such other analyses as may be indicated. Lard should contain not more than one per cent of free fatty

acids. The moisture content of kettle rendered lard should be not more than 0.1 per cent and that of steam rendered lard not more than 0.3 per cent. The melting point should be between 30°C. and 45°C. (86°F. and 113°F.).

Results of inspections. As in the case of canned or cured meats, lard and lard compounds, or lard substitutes, purchased by the army are usually produced by the larger packing houses and have been inspected by federal inspection agencies. If procured from local establishments, they should be prepared under the supervision of military or acceptable civilian inspection agencies. If evidence of such supervision is lacking, the lard should be rejected for purchase, or if in the possession of the Government, it should be very carefully examined before being issued for consumption. Any product found to be rancid, sour, mouldy or adulterated should be considered as unfit for food. If only a portion of the product is rancid, the remainder may be passed for food. If only the surface is mouldy, the mouldy portion may be removed and the remainder used for food.

Oleomargarine. Oleomargarine is a mixture of animal and vegetable fats in such proportions as to form a substitute for butter. The higher grade oleomargarines are made by emulsifying vegetable oils, oleo oil and neutral lard in milk, with added salt, and, in some instances, added butter fat. The poorer grades may contain stearine or tallow. Artificial coloring may be added, in order that the product will more closely resemble butter. Colored margarine is subject to a federal tax of 10 cents per pound, but may be purchased tax free for army uses.

The oleomargarine issued to the troops should be made from high grade oleo oil, neutral lard, cream or milk, butter and vegetable oils. It should contain between 2.5 per cent and 4 per cent of salt and not more than 14 per cent of moisture. The vegetable oil content should be not more than 15 per cent of the total mixture and the butter fat not less than 10 per cent of the fats. The butter used should score not less than 90 (page 556).

Oleomargarine is inspected in the same manner as lard. It should be free from rancidity, sourness, mould or foreign odors. The fat and moisture content, as determined by lab-

oratory examinations, should be that specified in the purchase specifications.

Sausage. Sausage is a mixture of comminuted meat and usually contains condiments. Sausages are made of fresh meat cuts, trimmings or offal parts. Any of the pure spices may be used and salt and saltpetre may be employed in the curing process. If sodium benzoate is used as a preservative, the fact that it is present and the amount must be stated on the label. Cereals may be used in proportion of not more than two per cent. Water or ice may be added as needed during the process of manufacture in quantities not to exceed three per cent, except that frankfort, vienna or bologna style sausage may contain enough water in excess of three per cent to render the product palatable.

Meat sausages are classified as fresh, smoked, cooked and dry sausages. Fresh sausages usually consist of fresh pork, or pork and beef. The smoked and cooked products include, among others, the frankfort, bologna, vienna, liver, wiener and luncheon sausages. The dry or summer sausages include the Italian, German, French and other styles of dried sausages, which may or may not be smoked.

Fresh sausage is prepared in bulk form or packed in cartons or cans or stuffed into casings. Smoked, cooked, or dry sausages are stuffed into casings or packed in cans or other containers.

The natural or animal casings consist of the stomach, large and small intestines and urinary bladders of hogs, the small intestines and urinary bladders of sheep and the weasands, large and small intestines, and urinary bladders of cattle.

Artificial casings are made of parchment paper, paraffined muslin bags or cellulose material of various kinds.

Owing to the nature of the products, special precautions should be taken to prevent contamination during the manufacture of sausage. All animals from which the meat or casings are derived should be subject to official ante-mortem and post-mortem inspections.

Fresh sausage may be kept for not longer than one week, and smoked or cooked sausages for not more than two weeks, in well operated and dry coolers. Dry sausages, if they are

kept dry, may be held without spoilage for long periods of time at a temperature of 36°F.

Sausage is inspected in the same manner as other meat products. Any sausage which presents evidence of deterioration, such as slime, mould, discolorations, or abnormal odor, or is sour, friable or unduly soft should be rejected for food. Any product which has not been prepared under the supervision of an official inspection agency should be considered as unfit for food, regardless of its condition at the time of inspection.

Where there is a question as to moisture or fat content, adulteration, or other factors affecting the purity of the product which cannot be determined by physical inspection, suitable samples should be sent to a laboratory for analysis. The sample should be placed in a tin, glass or other nonabsorbent container having a tight fitting lid. In order to preserve moisture the sample should not be wrapped before packing in the container.

CHAPTER X.

INSPECTION OF POULTRY, EGGS AND FISH

POULTRY AND EGGS

The term poultry includes chickens, ducks, geese, turkeys, pigeons and such other domestic birds as may be used for food.

The term egg usually includes only chicken eggs, although the eggs of other birds may be used as food.

Contamination of poultry. Poultry is generally subject to the same kind of contamination as meat products, though the tissues of poultry may afford a more suitable medium for the growth of organisms and thus augment the probabilities of post-mortem infection. While none of the diseases to which poultry is usually subject are thought to be transmissible to man, post-mortem inspections are of importance in preventing the consumption of food contaminated with organisms pathogenic for man. Ante-mortem inspections are of value principally as a means of detecting and preventing the purchase or issue of poultry which for esthetic or economic reasons should not be used as food.

Inspection of poultry. Poultry may be offered for purchase or received for issue as live poultry, or in a freshly killed, chilled, frozen or defrosted state. Fresh poultry may be drawn or undrawn. Poultry purchased for issue to troops should be undrawn and have the head and feet attached.

Poultry carcasses should be inspected for evidence of improper bleeding, which may be indicated by discolored areas or hemorrhagic spots where the feathers have been removed, decomposition of the tissues, bruises or any unsoundness or contamination which would render them unsuited for food.

Poultry should be rejected for purchase or issue if inspection reveals extensive decomposition or bruising of the tissues, fractures of the bones, parasitic invasion, or evidence of any of the following diseases:

Septicemia	Enterohepatitis (turkeys)
Infectious leukemia	Chicken pox
Coccidiosis	Contagious epithelioma
Sarcomatosis	Tuberculosis
Purulent peritonitis	Pneumonomycosis

Inspection of eggs. Eggs do not ordinarily serve as a transmitting agency for disease-producing organisms, although it is possible for micro-organisms to pass through the porous shell or reach the interior of the egg through a break in the shell. Eggs are usually inspected for the purpose of detecting those which, for esthetic or economic reasons, are unsuited for food, or which do not meet the requirements of purchase specifications.

Eggs are inspected primarily for freshness, soundness, size and cleanliness of shell, but color is also considered. Freshness should be determined by candling, or by a breaking test. Candling is performed by holding the egg between the eye and the opening of the candling apparatus in such a way that the condition of the egg contents is revealed by the transmitted light. Various devices for candling eggs are available or can be made. A typical apparatus for this purpose is shown in Fig. No. 116.

Unsoundness in the candled egg is indicated by mixing of the white and the yolk, adherence of the yolk to the shell, blood rings, heavily mottled or abnormally colored yolks, spots of movable air, discolored whites, size of air cells, or foreign bodies. The different grades of eggs which are satisfactory for issue to troops are shown in Plate No. 2. Eggs showing other conditions should be rejected.

If facilities for candling are not available, the general condition of a lot of eggs may be determined by breaking a certain number selected at random. Musty or sour eggs can be detected only by the breaking test.

If on piece inspection prior to purchase, either by candling or otherwise, a lot of eggs is found to contain any considerable

PLATE No. 2

U. S. SPECIAL

U. S. EXTRA

U. S. STANDARD

U. S. TRADE

Grades of eggs satisfactory for issue to troops. (Courtesy of the Ohio State Dept. of Agriculture, Columbus, Ohio.)

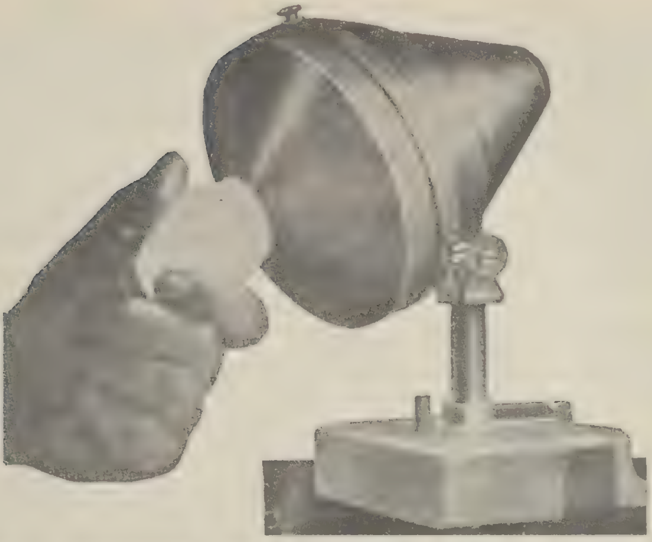


FIG. No. 116. Apparatus for candling eggs in daylight. (Courtesy of the S. C. S. Box Co., Inc., Palmer, Mass.).

proportion of cracked, broken, deteriorated or otherwise unsound eggs, the entire lot should be rejected.

All eggs which show evidence of unsoundness on inspection by candling or other tests, subsequent to purchase and prior to or at the time of issue, should be rejected for issue to troops.

FISH AND SEA FOODS

The food fishes include a wide variety of species. Those most commonly issued to troops include salmon, codfish, herring, tuna, and sardines. Fish may be offered for purchase, or issued, in a fresh chilled, frozen, canned or cured form. The sea foods which are usually purchased for use by troops include oysters, clams, crabs and shrimp. Sea foods may be fresh or canned.

Contamination of fish. The flesh of fish may contain chemical poisons which will produce illness in man or it may serve as a transmitting agency for disease producing organisms or toxins.

Most of the fish which contain chemical poisons are found in the tropics. Some kinds of fish are inherently poisonous at

all times while others contain physiological poisons only at certain times or places, for example, during the spawning season or in the tropics. Most of those which are constantly poisonous belong to the family *Tetrodontidae*, commonly known as puffers, or globe fish.

Other fish, such as parrot fish, jacks, trigger fish, or king fish, are reputed to be poisonous during certain seasons and at certain places in the tropics. The toxic substance is usually present in the ovaries and eggs, but may also be found in the head and liver. The roe of certain species of sturgeon is poisonous during the spawning season.

The toxic substance is not destroyed by boiling. In many instances, the exact chemical nature of the poison has not been determined, but it contains two toxic substances known as tetrodonin and tetrodonic acid.

The ingestion of physiological fish poison is followed by gastroenteritis with vertigo, nausea, salivation, abdominal pain, diarrhea, dyspnea and collapse (ichthyotoxism). Death may follow in a few hours . Recovery may occur after varying periods of illness.

Strict sanitary precautions must be observed in handling fish intended for human consumption. Otherwise, rapid deterioration characterized by putrefactive decomposition will occur as a result of the multiplication of contaminating organisms and the production of toxic substances which, when ingested, may cause illness.

The tissues of various fresh water fish, more especially pike and perch in the United States, may contain the encysted plerocercoids, or larvae, of *Diphyllobothrium latus*, or fish tapeworm, which, when ingested in a viable state, develop into the adult forms in the intestines (page 207). Thorough cooking will destroy the larvae and thus prevent infestation of man. They are not destroyed by smoking, drying, salting or freezing.

In the United States, *D. latus* is prevalent in the Great Lakes region. It is common in the lake regions of Europe.

Inspection of fish. In the inspection of fresh chilled fish, certain characteristic indications of soundness should be sought. If a fish is fresh and sound the following conditions will be present:

The gills will be bright red, usually closed, and have no abnormal odor.

The eyes will have a prominent appearance and the cornea will be transparent.

The scales will be adherent.

The skin will be free from malodorous slime and not discolored.

The flesh will be firm and only transient indentations will be made by pressure with the fingers.

The body will be stiff and the tail rigid.

The carcass will sink in water.

Conversely, fish which is decomposed and which is consequently unsuited for food will be found on inspection to possess one or more of the following characteristics:

The gills will have lost their normal bright red color and will be pale, yellowish brown, dark red or otherwise abnormally colored. They will be open, or can be be easily opened and may have an offensive odor.

The eyes will be sunken and opaque with a dull or decomposed cornea.

The scales will be loose and easily removed.

The skin may be covered with a malodorous slime.

The flesh will be soft and friable.

The carcass will be pliable and will float on water.

Any indication of infestation with parasites or contamination by fungi should be considered as rendering fish unsound and unsuited for food. The presence of worms may be evidenced by numerous small holes or small opaque bodies. Where pertinent, special care should be taken to determine if the fish are infested with larvae of *Diphyllobothrium latus.*

Frozen fish should be inspected for discoloration and abnormal odors. Defrosted fish should be inspected in the same manner as fresh fish.

The carcass of any fish should be rejected for purchase, or for issue, if it shows any evidence of unsoundness, injury, contamination, or of having been subjected to danger of contamination during handling.

Canned or cured fish products are inspected in the same manner as canned or cured meat products (pages 466 and 463).

CONTAMINATION OF SHELLFISH

Oysters are the most widely consumed of all shellfish and, because of the conditions under which they grow and are handled, they are the most frequently contaminated with pathogenic organisms.

Oysters thrive best in water the salinity of which is less than that of sea water and, consequently, producing areas are frequently located where the sea water is diluted with fresh water. Under these conditions, many of the waters in which oyster beds are situated are actually or potentially subject to contamination with effluents from sewerage systems or sewage treatment works. The food of the oyster consists of minute particles of organic matter, including bacteria and animal organisms, which are obtained by straining the water through the gills. Oysters grown in water containing sewage may, therefore, ingest pathogenic organisms and these organisms may remain alive and virulent for a sufficient length of time for the oysters to reach the market and the consumer.

Oysters are frequently eaten raw, or but partially cooked, and contaminated oysters are, for this reason, especially dangerous as a means of transmitting the causative organisms of intestinal disease. A number of epidemics of typhoid fever among civilian populations have resulted from the consumption of contaminated oysters. Transmission by oysters of the causal agents of food infections is also a relatively frequent occurrence.

Many individuals exhibit idiosyncrasies to shell fish, including oysters, clams, crabs or shrimp, which are usually manifested by urticaria or erythema, nausea and vomiting and, in some instances, by diarrhea. Such symptoms should not be confused with those of food infection.

Sources of contamination. Oysters may be contaminated with pathogenic organisms derived from sewage in the water on the beds where the oysters are grown. Oysters which have been removed from the beds may be stored for a time in other water prior to shipping and if the storage water is polluted with sewage, it may contaminate oysters which were originally free from pathogenic organisms. Oysters may be contaminated while being prepared for market in shucking houses or during the process of handling in local distributing stores.

Prevention of contamination. The production and handling of oysters is governed by state laws and regulations, in so far as factors which result in contamination, deterioration or adulteration, are concerned. The shipment of adulterated oysters, which includes contaminated products, in interstate commerce is prohibited by federal laws applying to all food products.

Certification of oyster shippers. The present method of preventing the sale of contaminated oysters is based on the cooperation of the state in which the oysters are produced with the United States Public Health Service. The state agency, whether it is the State Health Department, Shellfish Commission, Agricultural Department or other body which has jurisdiction over the oyster industry in the state concerned, supervises the harvesting, handling, shipping or marketing of the oysters within the state in accordance with the state laws and regulations. It determines the waters from which safe oysters may be taken, issues licenses to individuals permitting them to take oysters, and inspects and supervises the operation of establishments in which oysters are prepared for the market. The state, through this agency, issues certificates to firms or individuals who comply with the rules and regulations of the state. Copies of this certificate are submitted to the U. S. Public Health Service and if the latter agency finds that the rules and regulations of the state issuing the certificate are adequate and are properly administered, the name of the certified firm or person is placed on a list of shippers approved by the U. S. Public Health Service. This list is sent at regular intervals to the various state health departments.

No coercive measures are employed by the Federal Government to enforce this plan. The success of the plan depends on the cooperation of the oyster producing and the oyster consuming states. In some localities, the product shipped by uncertified dealers is excluded from the market by local health authorities, while in other instances, uncertified dealers may market their oysters and ship them in interstate commerce provided they comply with the laws pertaining to adulteration.

Only oysters marketed by certified dealers should be purchased for issue to troops. The names of certified shellfish shippers can be obtained from the local health authorities.

Purification of oysters. Oysters grown in contaminated water may be purified by storage in clean, sewage free, sea water. Purification is accomplished by the relatively rapid passage of clean water through the gills of actively feeding oysters. Under average conditions contaminated oysters will be purified by storage in clean water for a period of from 24 to 48 hours, that is, the average bacterial score will be reduced to 50 or less (page 485).

The water in which oysters are placed for storage should have the same salinity as that in which they were grown. When oysters are stored or "floated" in water the density of which is less than that in which they were grown, they become bloated or "fatter". The shipment of "floated" oysters is prohibited by federal law on the grounds that they are adulterated and that shipment in interstate commerce is a violation of the Federal Food and Drugs Act.

An actively feeding oyster obtains food by passing from seven to eight gallons of water daily through the gills which serve as a filter and retain micro-organisms and other food particles. The feeding habits of oysters are markedly influenced by the temperature of the water. Active and continuous feeding occurs in water having a temperature higher than 50°F. Oysters hibernate, that is, they cease feeding, when the temperature of the water is reduced to 45° F. or less. The shell is tightly closed for the greater part of the time, being opened only to admit the water necessary to provide oxygen. In order for storage in clean water to be effective as a purification measure, the temperature of the water must be such that the oyster will feed continuously and actively. Consequently, the water in which oysters are to be purified must have a temperature of more than 50° F.

Oysters may be purified in sea water which has been chlorinated and then dechlorinated with sodium thiosulphate or by aeration. Oysters will not feed in water containing an appreciable amount of chlorine.

The purification of oysters by storage in clean or chlorinated sea water is merely an added safeguard and should not

be employed as a substitute for clean water on the beds in which the oysters are grown. Oysters grown in water which is grossly contaminated with sewage should not be considered suitable for food, even though purified by storage in clean water. Those grown in water which may at times be subject to slight contamination can be rendered safe for consumption by this method of purification.

Sanitation and inspection of shucking establishments and oyster markets. The certification of oyster shippers provides only that the oysters have been taken from waters approved by the state in which the oysters were grown and have been prepared for the market in accordance with satisfactory rules and regulations. Certification does not insure against contamination during shipment nor after the oysters have been received at the local markets. In order to insure that the oysters purchased locally for use by troops are free from contamination, shucking establishments and other places in which the oysters are handled must be subject to supervision and inspection by either civilian or military authorities.

As a rule, oyster shucking and packing plants are licensed by state or municipal authorities and such license is granted only when the plant is properly located, constructed, equipped and operated.

The building in which the plant is housed should be so constructed as to provide adequate ventilation and lighting. All parts of the building where oysters are handled should be so arranged as to permit thorough cleaning by flushing with adequate drainage. Toilet and lavatory facilities, including hot water, soap, and clean towels, should be provided for the workers. The building should be screened against flies and adequate provision made for the disposal of wastes.

The plant should have an ample supply of potable water. Steam or boiling water should be provided for disinfecting utensils and apparatus. If steam is not available, a solution of calcium hypochlorite should be used as a disinfecting agent (page 526).

All containers for shucked oysters or utensils used in handling them should be of such character that they can be easily cleaned. They should be cleaned immediately after use and disinfected daily before using.

Employees in an oyster shucking or packing plant should wear clean clothing at all times and their outer garments should be made of washable material. All employees should be required to wash their hands thoroughly before starting to work and after visiting the toilet.

All employees should be physically examined for communicable disease, or to determine if they are carriers of a communicable disease, in accordance with the existing regulations of the civilian health department. No employee having a communicable infection or showing symptoms of illness should be allowed to continue to work.

Bacterial examination and scoring. Oysters are scored for the purpose of expressing their suitability as food. The score is based on the result of a bacteriological examination of the shell liquor, or an aqueous extract of the oyster meat, expressed in terms of the content of coliform organisms. The samples should be collected and transported and the examination conducted in accordance with the technique prescribed by *The Standard Methods for the Bacteriological Examination of Shellfish,* American Public Health Association. In the bacteriological examination of oysters, the presence of coliform organisms is used as an index of contamination with excreta in the same manner and under the same assumptions as in the analysis of water (page 358). Studies have shown that typhoid bacilli, and presumably other pathogenic organisms, penetrate into the body of the oyster where they may survive for from one week to a month.

Sampling. A sample of oysters in the shell consists of twelve oysters selected at random from the lot being inspected. The sample is transported to the laboratory in a cloth bag or other suitable container. If more than twenty-four hours are required for the sample to reach the laboratory, it should be packed in ice in such a manner as to prevent the ice water from coming in contact with the oysters.

Where shucked oysters are to be examined, the stock in the container from which the sample is to be obtained is thoroughly mixed, after which a sample of at least one-half pint of the oyster meats is removed with a sterile ladle or other utensil and placed in a sterile wide mouthed jar. The jar is then tightly stoppered. If more than three hours are required for the sample to reach the laboratory, or if the atmos-

pheric temperature is above 50°F., the stoppered jar containing the sample should be packed in ice.

Scoring. At the laboratory a composite sample is made from the shell liquor obtained from five to twelve oysters in shells, or by means of an aqueous extract of the shucked oysters.

Five 1 c.c. portions of the undiluted composite sample, five 1 c.c. portions of a 0.1 dilution and five 1 c.c. portions of a 0.01 dilution are placed in fermentation tubes containing standard lactose broth and incubated for 48 hours If gas is formed, further tests are made to confirm the presence of coliform organisms.

As a means of scoring and expressing the relative degree of contamination, the presence of coliform organisms in each fermentation tube is given the following numerical values:—

If present in 1 c.c. but not in 0.1 c.c., the value of 1.

If present in 0.1 c.c. but not in 0.01 c.c., the value of 10.

If present in 0.01 c.c., the value of 100.

The sum of the values obtained for a sample is the score for that sample, as shown by the following example:

Fermentation tubes	1.0 c.c.	0.1 c.c.	0.01 c.c.	Numerical values
1	+	—	—	1
2	+	+	—	10
3	+	+	—	10
4	+	+	—	10
5	+	—	—	1
				Score........32

Interpretation of score. Oysters which score more than 50 should be regarded as unfit for food. A score of 50 or less is of value only as confirmatory evidence, that is, it does not indicate that the oysters in question are safe, unless it is known that they were grown in clean water and handled in a sanitary manner. If the oysters have been prepared for the market by a certified shipper, a score of 50 or less indicates that the oysters in question are safe.

Inspection of oysters. Oysters are inspected prior to purchase, at time of issue or on receipt, or after being received in the kitchens of the using organization. The oysters pre-

pared by a certified shipper may be subject to sporadic and undetected contamination on the beds, they may spoil or become stale after being shipped, or they may be contaminated during transportation or while in the local retail markets. Consequently, a piece inspection is always made for evidence of spoilage, staleness or adulteration. Where practicable and pertinent, the inspection may include bacteriological examination.

Oysters, whether in the shell or shucked, are highly perishable. They deteriorate rapidly when improperly handled, first becoming stale and then spoiled. Both staleness and spoilage are evidenced by characteristic, disagreeable odors.

The shells of sound oysters are closed and all found on inspection to have open shells should be rejected. The exterior of the shells should be free from excessive quantities of slime or dirt.

A number of individual oysters are selected at random from the lot being inspected and opened for examination of the meats. Oysters of a lot showing any evidence of floating or fattening should be rejected. A dark or black ring on the inside of the shell is an indication of spoilage and a cause for rejection. The entire lot should be rejected if the samples selected present any abnormal odors or other evidence of staleness or decomposition.

Shucked oysters should be rejected if any abnormal odor or a gassy or milky appearance can be detected on inspection. As in the case of oysters in the shell, shucked oysters should be rejected if there is any evidence of floating.

Oysters which have been frozen spoil rapidly after defrosting. Defrosted oysters should be consumed or prepared for consumption immediately after defrosting.

Oysters may show a green or pink discoloration. A copper green discoloration may be distributed through the body, particularly in the visceral portion. This form of green discoloration is thought to be due to copper derived from the water in which the oysters were grown. In other instances, the gills and mantle may exhibit a dark green coloration which is due to the ingestion of quantities of the diatom, *Navicula fusiformis.* In some parts of Europe the green gilled oyster is regarded as more desirable, but it has not met with favor in the United States.

While there is no evidence that green colored oysters, whether colored by copper or by *Navicula fusiformis*, are detrimental to the health of the consumer, they are generally regarded as undesirable for food and should be rejected for issue to troops.

Shucked oysters may develop a pink color while in storage or transit. This color is due to a species of chromogenic yeast with which the oysters have been contaminated while being prepared and packed for shipment. The yeast will grow at low temperatures, is resistant to drying, and is difficult to remove from the oysters by washing. It is killed by a 1 to 2500 dilution of formaldehyde and the inoculation of oyster stock in shucking and packing plants can be prevented by disinfecting all utensils, benches, bins and wood work with this solution at suitable intervals. While there is no evidence that the pink yeast is injurious to the consumer, the presence of the organisms in oysters is evidence of carelessness in handling, and pink oysters should be rejected for issue to troops.

Canned oysters are inspected in the same manner as canned meats (page 466).

Clams, crabs, shrimps, lobsters, and other shellfish. Ordinarily, only canned crabs, clams, shrimps and lobsters are used in army messes, but occasionally, these shellfish may be issued fresh. The procedure followed in inspection of the fresh products is, in general, the same as for oysters. The canned products should be inspected in the same manner as canned meat (page 466).

CHAPTER XI.

DAIRY AND MILK PLANT SANITATION

The production and handling of milk must be continuously supervised and regulated by competent authority, from its source to the time and place of consumption. The milk and milk products issued to the troops must be adequately safeguarded, first, against contamination with pathogenic organisms, and second, against adulteration which would impair their food value.

Milk is a most important agency of transmission for certain pathogenic organisms. It is usually served in an uncooked state, and consequently many of the organisms which it may contain will be viable when ingested. It constitutes a culture medium in which many organisms will grow profusely if the temperature is suitable. Further, the conditions under which milk is produced and subsequently handled provide numerous opportunities for inoculation with pathogenic organisms, unless contamination is prevented by strict and continuous enforcement of control measures.

Disease transmission by milk. The diseases most commonly transmitted to adults by milk are typhoid fever, the common diarrheas, undulant fever, septic sore throat, diphtheria, and scarlet fever.

The transmission of disease to troops by milk is combatted by measures which prevent contamination with pathogenic organisms, by procedures which destroy such organisms in the milk before it is consumed, and by regulations and orders which will prevent the issuance to troops of milk contaminated with disease producing organisms.

The measures employed to protect the consumer from contaminated milk include the physical examination and biological

testing of the cows for diseases transmissible to man, the supervision and control of the methods of handling the milk to prevent contact with potential sources of infection, destruction of the organisms in the milk by pasteurization, and the physical examination of milk handlers by medical officers or local civilian health authorities.

Bacterial contamination. Milk, as it comes from the udders of healthy cows, contains relatively few bacteria, but the organisms that subsequently enter the milk will, under favorable conditions, increase so rapidly that the milk delivered to the consumer may be heavily contaminated. Most of these organisms are saprophytes which do not produce disease or affect the quality of the milk. Some of them, however, produce changes in the milk, such as souring, abnormal odors and tastes, or proteolytic changes, while others are pathogenic and cause disease in man.

The bacteria in milk are derived either from the udder of the cow or from sources of infection with which the milk comes in contact during or subsequent to milking. The milk in the udder may contain tubercle bacilli, or the causative agents of undulant fever or of septic sore throat. During and after milking, the milk is, under average conditions, subjected to contact with many sources of bacterial contamination. It may be inoculated with organisms by the hands or clothing or by secretions from the respiratory tracts of those who handle the milk. Milk may be contaminated by material which falls from the flanks and udder of the cow during milking, or with bacteria from the surfaces of utensils, apparatus or containers used in its preparation and transportation. It is probable that utensils employed in handling the milk are the most common immediate source of contamination.

BOVINE TUBERCULOSIS

Bovine tuberculosis is primarily a disease of cattle which is transmissible to man by milk and meat. It is relatively more prevalent among dairy cattle that are kept in close contact with each other in small pastures or in stables than in beef cattle on open ranges. The exact incidence of bovine tuberculosis cannot be determined, but it is estimated that about 1.5 per cent of all cattle in the United States have the disease.

Throughout a large part of the United States the tuberculin testing of cattle with the elimination of the positive reactors has reduced the prevalence of tuberculosis among cattle in certain areas to less than 0.5 per cent. The sections of the country where such prevalence obtains are known as modified accredited areas (*infra*). While bovine tuberculosis is present in all parts of the United States, it varies greatly in prevalence in the different sections. The incidence is greater in New England, the North Atlantic states, and in California, than in the middle west, southern or other far western states.

Tuberculosis in cattle may involve any of the tissues of the body but the pulmonary form is the most common type. The intestines, liver, spleen, kidneys and serous membranes are frequently involved. Tuberculosis of the udder occurs in from one to three per cent of tuberculous cattle. The lymph glands draining infected tissues are always secondarily involved, while primary infection may occur in young cattle.

Tubercle bacilli may remain viable in raw milk until after the milk decomposes. Cream contains a larger proportion of tubercle bacilli than the remainder of the milk, due to the tendency of the organisms to adhere to the fat globules. The bacilli are present in the products of infected milk, including cream, ice cream, butter and cheese. In unsalted butter, the organisms will survive in a virulent state for six months and in salted butter for three months. While fresh cheese may contain virulent tubercle bacilli, they are seldom found in the cured product.

Transmission to man. Tubercle bacilli are excreted in the discharges from the respiratory tract and in the feces, urine and milk. They may be present in large numbers in the feces of cattle having the pulmonary form of the disease, as the infected sputum is frequently swallowed and the organisms are not destroyed in the digestive tract.

It is probable that in most instances the organisms are transferred to milk by fecal material which falls into it during the milking process. Milk produced by animals having tuberculous mastitis is directly infected while in the udder. The dust, litter or manure in stables where cows are milked may also serve to carry the bacilli into the milk.

Diagnosis of tuberculosis in cattle. Tuberculosis in cattle may be diagnosed either by clinical symptoms or by the re-

action to tuberculin. Usually, the diagnosis is based on the tuberculin test as, in many instances, the disease may be present without producing demonstrable clinical signs.

Tuberculosis should be suspected when the animal shows loss of weight not accounted for by other conditions. As the disease is also characterized by lymphadenitis, an enlargement of the glands of the throat or those located at the point of the shoulder or in the udder, may be indicative of the disease. Tuberculosis may also be evidenced by a cough, increased respiration, elevated temperature, or diarrhea.

The tuberculin test. The tuberculin test is the most reliable method of determining the presence of tuberculosis in cattle. Three methods of tuberculin testing have been developed, any one of which can be used alone or in combination with one or both of the other tests. These are the intradermic, the subcutaneous, and the ophthalmic tests. The intradermic test is the most reliable of the three, and is the official test in the army. It is now almost universally employed by civilian workers and the subcutaneous and the ophthalmic tests are applied only under selected conditions. Each test is based on a specific reaction of the tissues concerned to the presence of tuberculin. *In order for the results to be reliable, any tuberculin test must be made and interpreted by a well trained worker, preferably, in the military service, by a veterinary officer.*

Tuberculin for testing cattle at military stations is supplied by or through the Army Veterinary School. Material for testing civilian owned animals should be obtained from authorized state agencies or from the Federal Bureau of Animal Industry.

All animals to be tested should be physically examined for clinical signs of tuberculosis or evidence of other conditions which might interfere with or modify the reaction to the tuberculin. In preparing animals for testing, they should be stabled, fed and watered in the usual manner and in their usual surroundings. If restraint is necessary, it should be applied so that the animal will not become unduly excited or nervous. An animal which has been tuberculin tested should not be retested until after at least 30 days have elapsed.

Syringes and needles which are to be used for injecting tuberculin should be sterilized by boiling. The needles should be kept in alcohol when not in use. A five per cent solution of carbolic acid may be used in lieu of boiling.

The intradermic test. The intradermic test consists of an injection of tuberculin into the skin which, in tuberculous animals, produces swelling, induration, or discoloration at the site of injection. The injection is made into one of the caudal folds and the fold on the opposite side is used as a control. The site of the injection is cleansed and from one-thirtieth to one-twentieth of one c.c. of tuberculin is injected between the layers of the skin.

An additional test, which is frequently used, consists of injecting from one-twentieth to one-thirtieth of one c.c. of tuberculin into one labium of the vulva at the junction of the skin and the mucous membrane. The other labium is used as a control. In testing male animals the injection is made into the border of the anus at the junction of the skin and the mucous membrane.

The site of the injection and the control tissues are examined 72 hours after injection and, in suspicious cases, or where the animal is known to have been exposed to infection with tuberculosis, on or about the 120th hour and thereafter as necessary.

The reaction is negative if there is no swelling, induration, or discoloration of the tissues, or involvement of the lymphatics 72 hours after injection. A positive reaction is manifested by either a circumscribed or a diffuse swelling or induration of the injected tissues, involvement of the caudal or the vulval lymphatic chain, or discoloration of the vulval or anal mucous membrane. A suspicious reaction is characterized by any disturbance of the tissues at the site of the injection which is too transient or too slight to be regarded as positive, but which does, nevertheless, indicate a reaction to the presence of tuberculin.

Reactions to intradermic injections of tuberculin are classified for record purposes, as "negative", "suspicious", "positive slight", "positive well marked", and "positive extensive". If, in addition to other symptoms, there is also discoloration of the vulval or anal mucous membrane, the reaction is recorded as "positive slight, discoloration", "positive well marked, discoloration", or "positive extensive, discoloration". If the reaction is manifested only by discoloration of the vulval or anal membrane, it is recorded as "positive discoloration". The official abbreviations, or symbols, used in recording the character of the reaction are, "N" for negative, "S" for suspicious, "P. sl." for positive slight, "P. wm." for positive well marked, and "P. ex." for positive extensive. If discoloration of the vulval or anal membrane is also present the abbreviation "discl" is added to the symbol

indicating other evidence of a positive reaction, as, for example, "P. wm. discl." Discoloration of the vulval or anal membrane alone is recorded as "P. discl."

Disposition of reactors to tuberculin. All animals reacting positively to tuberculin should be immediately removed from any herd serving as a source of milk supply for troops, and until they are removed the milk obtained from the entire herd should be rejected for human consumption. In the case of government owned herds, positive reactors should be immediately destroyed. Those found in civilian herds are disposed of by local authorities in accordance with the provisions of the laws and regulations under which they are tested.

If suspicious reactors are found in a government owned herd, they should be immediately removed, isolated and retested at intervals of 60 days until definitely positive or negative reactions are obtained. If found in a civilian owned herd, from which milk is obtained for troops, the entire supply of milk from that herd should be rejected until the suspicious reactors are removed.

Prevention of transmission. Two general control methods are employed in preventing the transmission of tuberculosis from cattle to man by milk and milk products. First, animals having tuberculosis are eliminated as a source of milk supply by destruction of those which show a positive reaction to the tuberculin test, and, second, all milk which is to be consumed as such, or from which milk products, such as cream, ice cream or butter, are to be made, is pasteurized to destroy all tubercle bacilli.

Tuberculosis free accredited herd plan. The general plan for the eradication of tuberculous dairy cattle, which has been sponsored by the federal government and adopted by many of the states, provides for tuberculin testing of all the animals in a given herd, and the destruction of positive reactors with the payment of an indemnity to the owners by government agencies. However, as the presence of one tuberculous animal in a dairy herd will result in the infection of the entire milk supply, the elimination of individual positive reactors to a single tuberculin test does not insure the continued freedom of the herd, as a unit, from tuberculosis. Consequently, the tuberculosis free accredited herd plan has been evolved to

insure uniformity of procedure, and to provide a means of maintaining a dairy herd free from tuberculosis.

The accredited herd plan provides that when all the animals of a dairy herd have been found to be free from tuberculosis by two successive annual, or three successive semi-annual tuberculin tests and physical examinations, the owner is given a certificate to this effect by the state or federal government. The owner must also comply with certain regulations relative to the maintenance of sanitary conditions and the admission of new animals to the herd. The certificate is good for one year after which the herd is retested and if no tuberculosis is found, the certificate is renewed. All tests and examinations must be performed by an accredited veterinarian.

Modified accredited areas. Under the supervision of the Bureau of Animal Industry, United States Department of Agriculture, working in cooperation with the various state agencies, areas or sections in which the prevalence of tuberculosis in the cattle population has been reduced to 0.5 per cent or less are designated as modified accredited areas. In many instances a modified accredited area is a county. On November 1, 1935, 2709 counties had been designated as modified accredited areas. The incidence of bovine tuberculosis in a modified accredited area is controlled by tuberculin testing and retesting of the herds and by rules and regulations governing the disposition of diseased animals and the movement of cattle into the area.

Milk for troops from tuberculin tested herds. The milk supply for troops should be obtained from accredited herds. If an accredited herd is not available, milk should be obtained only from a herd where the individual cows have been found to be negative to the tuberculin test.

BOVINE INFECTIOUS ABORTION
(*Bang's disease*)

Infectious abortion in cattle is caused by *Brucella abortus* (*Bacillus abortus*). The organisms are transmitted from animal to animal principally by contaminated food and water. The organisms may enter the body through the unbroken skin or membrane. Rarely, infection may occur through the genital tract.

The embryonic and uterine tissues are most readily infected with *Brucella abortus*, especially the epithelium of the chorion. The organism is also to be found in the udders of infected cows and in the seminal vesicles of the males. Subsequent to abortion or parturition, it disappears from the uterus but frequently remains in the udder for long periods of time.

In man, infection with *Brucella abortus* produces a form of undulant fever which is practically indistinguishable, clinically, from the undulant fever caused by *Brucella melitensis* (*Micrococcus melitensis*) of goats and *Brucella abortus - suis* of swine (page 191).

Diagnosis of infectious abortion in cattle. Clinically, infectious abortion in cattle is characterized by abortion. Repeated abortions may occur, but an immunity is usually conferred by one or, at the most, two attacks. Abortion in cattle, especially if several members of the same herd have aborted, should be regarded as due to infection with *Brucella abortus* until proven to be due to another cause.

In many instances, however, cows infected with *Br. abortus* do not abort and the diagnosis can be made only by complement fixation or agglutination tests. The agglutination test is ordinarily employed for this purpose and may be performed either with blood serum or with whey from the milk of the suspected animal. Usually, blood serum is used.

A positive agglutination reaction in a dilution of 1:100 or more is considered to indicate that the animal is, or has been, infected with *Brucella abortus*. Usually, the blood serum of animals having an udder infection will show a positive reaction in dilutions of 1:200 or higher. A positive reaction in a dilution of 1:50 should be regarded as suspicious.

Prevention of transmission by milk. The transmission of *Brucella abortus* to man by milk is prevented either by pasteurization of the milk or by the eradication of infectious abortion from dairy herds. Measures for controlling the spread of infectious abortion among cattle, which necessarily decrease the amount of infection transmitted to man, are based on the detection of infected animals and their removal from contact with susceptible animals.

Procedures or plans for the prevention of infectious abortion, like those for the eradication of bovine tuberculosis, are controlled by a central agency, such as the state or federal govern-

ment. A typical plan provides for the segregation of all cattle showing a positive blood serum agglutination reaction and the observance of certain sanitary precautions. A herd is kept free from infectious abortion by the removal of carriers, as detected by repeated blood tests, and by adding to the herd only animals which have been proven to be free from the infection.

Prevention in a government owned herd. Any government owned dairy herd which is supervised by military authorities should be kept free of animals infected with *Brucella abortus*. Initially, the blood of each animal in the herd should be tested by the agglutination test and all positive reactors removed and so segregated that there will be no physical contact between them and the remainder of the herd. If positive reactors are found and removed when the first test is made, the remainder of the herd should be retested at intervals of 30 days until no more positive animals are found. When all the animals in the herd are negative to an initial blood test, either the first test or a 30-day test, they should be retested after an interval of 60 days in order to detect any that may have been in the incubationary stage of the disease at the time of the initial negative test. Thereafter, each animal should be tested twice before being bred. Bulls should be subjected to the same tests as the cows.

No animal which is not proven by blood tests to be free from infection should be placed in a negative herd. Calves from reacting dams should be kept separate from the negative herd. The positive reactors should be disposed of, but if retained for dairy purposes, they must be completely separated from the negative herd and their milk must be pasteurized under adequate supervision before issue to troops. When positive reactors are detected and removed from a herd, the premises should be thoroughly cleaned and disinfected.

DAIRY SANITATION

The sanitary condition of a dairy barn and premises should be such that contamination of the milk will be reduced to a minimum and the transmission of infection from animal to animal prevented or rendered amenable to control.

In many instances, the sanitation of civilian owned dairies which furnish milk for troops is governed by local laws which, if adequate and enforced, provide the necessary protection.

Nevertheless where practicable, such dairies should be inspected by army inspectors. Government owned dairies should be operated and maintained in conformity with sanitary standards as promulgated in regulations and local orders.

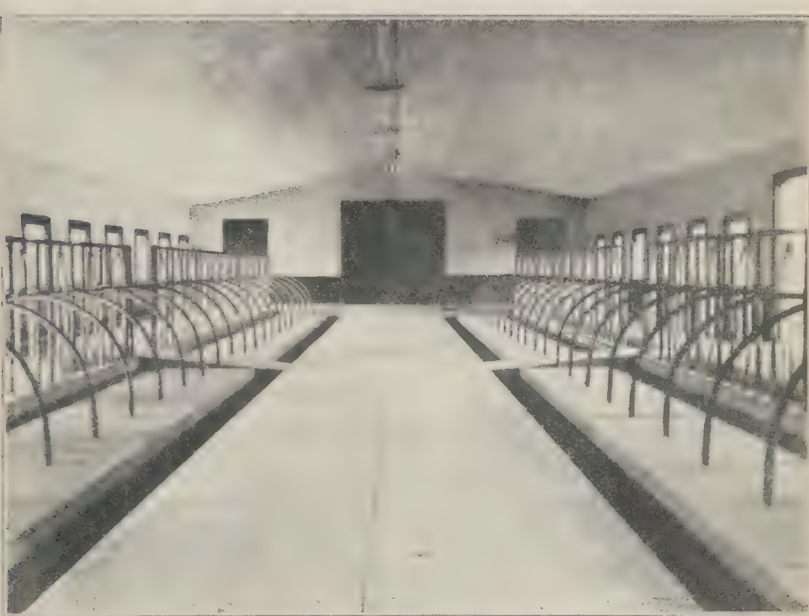


FIG. No. 117. Interior of dairy barn showing stanchions and location of gutters. (Courtesy of the Bureau of Dairy Industry, U. S. Dept. of Agriculture, Washington, D. C.).

Sanitary standards for dairy barns and premises. The ground accessible to the cattle should be well drained and free from accumulations of mud, stagnant water, rubbish, manure or any other material which would serve as a source of contamination or as a breeding place for flies.

Construction of the barn. All floors or platforms on which the animals stand should be watertight and made of a non-absorbent material, preferably concrete. They should slope toward drainage outlets so as to facilitate cleansing by scrubbing or by flushing with water under pressure from a hose. Manure gutters should be provided in all dairy barns. They should be of concrete and so constructed that they can be readily cleaned and drained (Fig. No. 117).

The ceiling and walls of that portion of the barn used to house the cattle should be smooth, and sufficiently tight to be

dust-proof. They should be constructed of material which will permit cleansing with water.

Light and ventilation. At least two, and preferably four, square feet of window area should be provided for each animal stanchion, and the windows should be so arranged that the light is distributed throughout the barn. A minimum of three square feet of window area per stanchion should be required in barns used to stable government owned animals.

Not less than 400, and preferably 600 or more, cubic feet of air space should be provided for each animal. Where practicable in cold climates, not more than 1000 cubic feet of air space should be allowed per animal in large barns so as to conserve animal heat. Ventilation may be effected either by a controlled system of exhaust ducts or flues, or by means of windows. If windows are used for ventilation, they should be of the swinging type and so constructed that they tip inward at the top.

Water supply. The water supply for the animals must be clean and fresh, and a potable supply must be available for the workers and for washing utensils.

Waste disposal. A flush toilet should be provided for the workers and maintained in a sanitary condition. Facilities for the washing of hands should be installed in or near each toilet room, including hot water, soap and towels.

Manure should be removed to a distance of at least 50 feet, and preferably to more than 100 feet from the barn. Where practicable, manure should be removed from the vicinity of the barn to fields or compost pits, but in any event it must be so stored or placed that it is inaccessible to the cattle and will not drain back onto the ground around the barn or milk house. Suitable measures should be taken to prevent fly breeding in the manure (Chapter XVII).

No liquid wastes of any kind should be permitted to accumulate in, or on the ground adjacent to the barn or milk house but should be carried away from the premises by underground drains.

Care of dairy barn. The walls and ceiling of the barn should be kept free of dust and dirt. The floors, manure gutters, mangers and stanchions should be cleaned with brooms and by flushing at least once a day. If the animals are confined to the barn, as during inclement weather, the floors and gutters should be cleaned at least twice a day, and oftener if necessary.

No bedding, forage or other dust-producing material should be stored in that part of the barn in which the animals are stabled, nor in adjacent portions of the building unless separated therefrom by dustproof partitions and ceilings.

FIG. No. 118. Dairy barn showing location of detached milk house. (Courtesy of the Bureau of Dairy Industry, U. S. Dept. of Agriculture, Washington, D. C.).

Milk house. The milk house is a building or room into which the milk is taken immediately after removal from each cow and where it is strained and cooled. Facilities should be provided in the milk house for cleansing and disinfecting the utensils. If the milk house is a room in the dairy barn, it should be completely separated by a screened areaway from that part of the barn in which the animals are stabled.

The floor of the milk house should be made of concrete. The walls should be made of non-absorbent material and so finished or painted that they can be scrubbed with soap and water. The floor should slope towards drainage outlets to facilitate cleaning with water under pressure.

All windows, doors or other openings should be screened so as to prevent the entry of flies. The interior of the milk

house should be kept scrupulously clean at all times. The floor and walls should be scrubbed or hosed with water under pressure at least once each day, and preferably just before each milking.

Care of the dairy cows to prevent contamination of the milk. In order to produce good milk, dairy cows must be properly fed, watered, stabled, groomed and exercised. The forage should be of good quality and old forage or rubbish should not be allowed to accumulate in or on the mangers, racks or feeding floor.

The bedding should consist of clean, absorbent material, such as dry straw, fodder, leaves or shavings.

Drinking troughs or basins should be cleaned at semi-weekly intervals and the water supply should be clean and fresh.

Weather permitting, dairy cows that are not pastured should be turned out to exercise in a clean yard for at least two hours daily.

MILKING

The milking process includes milking the animals, cooling and straining the milk, and pasteurization of the milk at the dairy or its preparation for shipment to a milk depot.

Milk handlers are those persons who come in contact with the cattle, the milk, or the utensils. These persons are the milkers and those who handle the milk subsequent to milking, as well as those who care for the cattle, or clean and otherwise handle utensils and apparatus.

The chances of contaminating the milk are, under average conditions, greater during the milking process than at any other time. Contamination may enter the milk in material falling from the flanks of the cow or from the external surface of the udder and teats. Milk may be infected by organisms from the respiratory tract or hands of the milk handlers. In some instances, the dust in the air may serve as a medium for transporting organisms into the milk. Contamination during the milking process can be greatly reduced by proper grooming of the animals, cleanliness of utensils and surroundings, and attention to the health and cleanliness of the milk handlers.

Grooming of cows. Immediately before each milking the flanks, legs and tail of the cow should be curried and brushed free

FIG. No. 119. Grooming cows before milking. (Courtesy of the Bureau of Dairy Industry, U. S. Dept. of Agriculture, Washington, D. C.).

of visible dirt. The flanks, tail, legs, udder and teats should be washed with warm water or with a chlorine solution containing at least 50 parts per million of free chlorine and wiped dry with a clean cloth or with paper towels (Figures No. 119 and 120). The hair on the flanks, legs, tail and udder should be kept clipped short.

Care of utensils. The utensils include the milk pails, milking stools, milking machines, tanks or other containers, coolers and bottles. Metal containers, such as the milk pails or milk cans, should be made of heavy seamless tin or of heavy tin with smooth seams. Utensils having rough, dented, broken or rusty surfaces, or those made of rough absorbent material, are difficult to keep clean and free from contamination. The milk pail should be the small top or small mouth type, so as to reduce as much as practicable the quantity of contaminated foreign material entering the pail (Fig. No. 121).

All utensils should be thoroughly cleansed and disinfected and so stored when not in use that they will be protected from

FIG. No. 120. Grooming cows before milking. (Courtesy of the Bureau of Dairy Industry, U. S. Dept. of Agriculture, Washington, D. C.).

dust or other contamination. The utensils should be rinsed in cold water and then thoroughly washed in hot soapy water, or a hot alkaline solution (solution of washing powder), to remove the milk film and deposits of milk substances. Whenever practicable, live steam should be used to disinfect all utensils. If steam is not available, disinfection may be effected by immersing in or thoroughly rinsing with boiling water or with water containing at least 50 parts per million of free chlorine (page 526). The cleansed and disinfected utensils should be stored in cabinets or placed on racks in such a manner that they will not be recontaminated prior to being used again.

The milking stools should be scrubbed after use and kept clean so that they will not soil the hands of the milker.

Milking machines, when properly used, prevent contamination of the milk by the hands of the workers or by dust or manure. However, to prevent the growth of bacteria in the tubing and different parts of the machine between milkings, and subsequent contamination of the milk, all parts of the machine, and particularly the tubing and teat cups, should be thoroughly

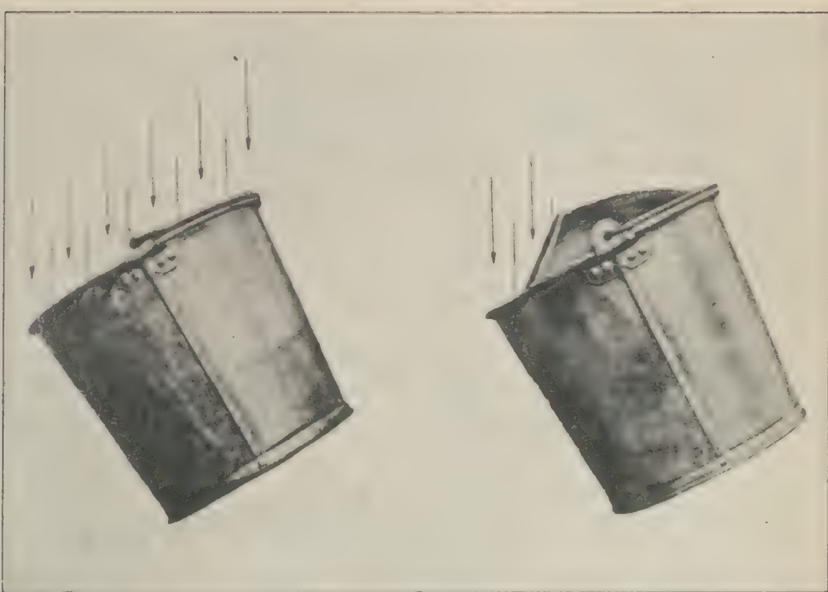


FIG. No. 121. Left—Ordinary pail which, because of the unprotected top, is not suitable as a milk pail. Right—Small mouth milk pail which affords maximum protection against contamination. (Courtesy of the Bureau of Dairy Industry, U. S. Dept. of Agriculture, Washington, D. C.).

cleansed and disinfected after each milking. When not in use, all tubing and teat cups should be kept immersed in water containing not less than 50 parts per million of free chlorine.

Health and cleanliness of the milk handlers. Milk handlers, including those who groom the cows, should be provided with clean outer clothing, preferably of washable material. Special garments should be furnished milk handlers to be worn while working with the milk or utensils. Clean garments should be stored in a clean, closed place when not in use.

The hands of the milkers should be thoroughly washed with warm water and soap and dried with a clean towel immediately prior to each milking. Milking with wet hands should not be permitted.

Milk handlers should be subjected to the same physical examinations as permanent food handlers (page 588). All milkers should be carefully observed each day by the individual in charge for evidence of illness, and no person who presents any symptoms of illness, especially coryza or other respiratory disease, should

be permitted to come into direct or indirect contact with the milk.

Straining and cooling. The milk from each cow should be taken at once to the milk house to be strained. The practice of filling a large can on the floor of the milking barn should not be permitted. Straining serves to remove the coarser suspended matter but does not materially reduce the bacterial content of the milk. Milk may be strained through a double thickness of cheesecloth, a cotton filter cloth, or through sterilized cotton held between two plates of perforated metal. Straining cloths should be sterilized by boiling before use.

Cooling inhibits the multiplication of bacteria and is an essential step in the production of good milk. The milk from each cow should be cooled as quickly as practicable to a temperature of 50°F., or less, and maintained at or below that temperature until it is ready for pasteurization. Under any circumstances milk must be cooled to a temperature of 50°F. or less within two hours after milking. If cooling facilities are lacking at the dairy, the milk must be delivered to a milk plant (*infra*) within two hours after milking.

The milk should be cooled as rapidly as possible. Rapid cooling may be accomplished by either a cone or tubular surface cooler.

The cone cooler is a cone shaped apparatus, the interior of which is filled with cracked ice and water, or contains coils for the circulation of cold water, ice water, or brine. The milk flows downward in a thin sheet over the outside surface of the cone into a trough receptacle at the bottom. The temperature of the cooled milk is maintained at the desired point by storage in ice boxes, refrigerators or cooling tanks.

Surface coolers are difficult to keep clean and in small dairies, where the facilities for cleaning and disinfecting surface coolers are inadequate, cooling in the can may prove to be the most satisfactory method. Milk is cooled in the can by either dry-box or wet-tank storage. In dry-box storage, cooling is usually accomplished by mechanical refrigeration, although ice may be used. Where mechanical refrigeration is used, the compressor should be located outside the milk room or milk house.

In wet-tank storage the cans of milk are placed in a tank containing ice water or water which is cooled by mechanical refrigeration. Concrete tanks are more durable and more easily cleaned than wooden tanks, but a lower temperature can be more easily

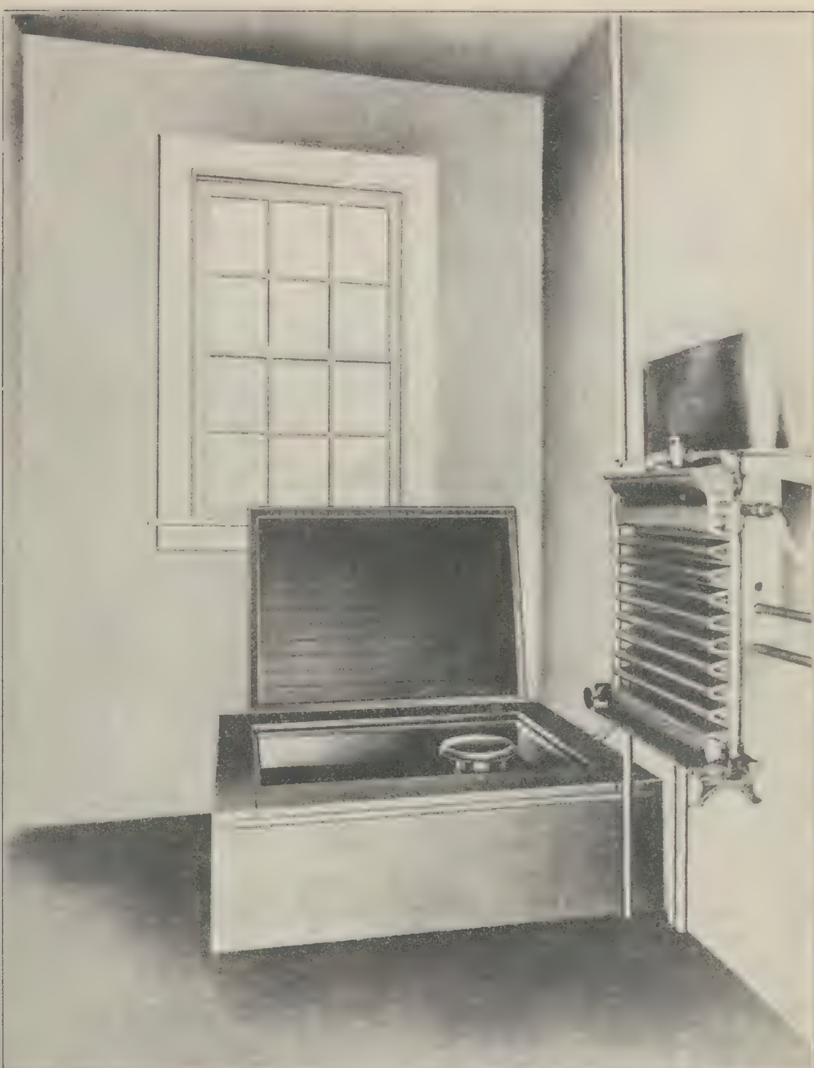


FIG. No. 122. Milk cooling apparatus. Mechanical refrigerator with cooler and wet-tank. (Courtesy of the Bureau of Dairy Industry, U. S. Dept. of Agriculture, Washington, D. C.).

obtained and maintained in the latter than in the former. Where practicable, cooling tanks may be made of wood and insulated with cork. Two or more tanks should be installed, so that ice or power may be conserved by placing one or more out of service when the milk supply decreases, or during the winter season. The tank should be equipped with a clean-out pipe or outlet in

the bottom and an overflow valve which will hold the water at a level higher than that of the milk in the cans.

The milk may be pre-cooled in a vat containing cool water but no ice. Pre-cooling without the use of ice or mechanical refrigeration may be effected by passing the milk over a cone or tubular surface cooler in which cool water only is used (Fig. No. 122). The cans of partially cooled milk are then transferred to a dry-box or wet-tank cooler.

The warm milk should be handled as little as practicable. When cooled in cans, the can into which the milk is poured from the milking pails or milking machine should be used for cooling. The milk should not be stirred in an effort to promote rapid cooling.

MILK PLANTS

The place where milk is pasteurized is commonly known as a milk plant, or pasteurizing plant. A civilian owned milk plant is, as a rule, located in the community to which the pasteurized milk is supplied, and the raw milk is delivered to the milk plant from one or more dairy farms. A milk plant may be located on the dairy farm where the raw milk is produced, but this is usually true only in the case of small plants. At military stations, where the raw milk is obtained from a government owned herd, the milk plant is usually located on the military reservation.

Large milk plants ordinarily receive milk once a day, usually during the morning hours. In the operation of smaller plants, and particularly those at army stations, milk may also be received in the evening, if the facilities for cooling the milk at the plant are more efficient than those available at the farms where the milk is produced.

Each can of milk should be inspected for objectionable tastes and odors as soon as it is received at the pasteurizing plant. If an abnormal taste or odor is detected, the can of milk showing such defects should be rejected. Samples should be taken at this time for tests for butter fat content, if the milk is graded on a butter fat basis. Samples are also taken for bacteriological and sediment tests (page 547).

When the milk is received at the plant it is usually poured into a weigh tank, which consists of a container placed on a scale. Occasionally the milk is weighed or measured in the cans in which

it is delivered by the producer. A drip saver may be installed if the volume of milk handled is sufficiently large to justify its use. The drip saver is an apparatus on which the empty milk can is placed for drainage and which will receive and collect the drippings from the cans.

FIG. No. 123. Apparatus for disinfecting milk cans, and weigh tank. (Courtesy of the Creamery Package Manufacturing Co., Chicago, Ill.).

The milk collected in the weigh tank is usually dumped into a storage or dump tank or vat where it remains until ready for pasteurization. A part or all of the milk may pass directly from the weigh tank to the pasteurizer, particularly if the positive holding method of pasteurization is employed (page 509).

Storage tanks are insulated and equipped with cooling devices consisting either of a jacket or revolving coils containing a cooling medium, such as brine or ice water. The milk in the storage tank may be agitated by means of air blown in from the bottom or by revolving paddles or coils. Storage tanks should be glass lined and so constructed that all parts are readily accessible for cleaning.

The milk is usually clarified at the milk plant to remove the coarser particles of dirt. A clarifier may be employed which removes the dirt by centrifugal force, or the milk may be filtered through layers of cheesecloth and cotton. Usually, the milk is clarified before heating, but in some plants it is more practicable to clarify the milk after it has been pasteurized.

Pasteurization. Pasteurized milk is milk every particle of which has been heated to from 142°F. to 145°F. and held at that temperature for not less than 30 minutes. In order to insure that the temperature of the milk in every part of the pasteurizing apparatus is actually not less than 142°F. at any time during the pasteurizing process, a temperature tolerance of 1½°F. should be allowed and the thermometer readings should be not less than 143½°F. continuously throughout the holding period.

While pasteurization will destroy all milk-borne pathogenic organisms, it does not sterilize the milk. Certain of the heat resistant bacteria, which usually constitute from one to ten per cent of the total bacterial content of raw milk, escape and will eventually produce spoilage of the pasteurized milk. Pasteurization is not a substitute for cleanliness in the production of the milk, nor should measures for preventing the contamination of the raw milk be neglected because the milk is to be pasteurized.

A temperature of more than 145°F. tends to impair the creaming ability of the milk, but the actual butter fat content is not reduced. Milk heated to a temperature of 145°F. for 30 minutes will show an apparent slight decrease in cream volume but not enough to be of any practical importance. Temperatures above 145°F., when maintained for 30 minutes, produce a pronounced reduction in creaming ability, so that at 148°F. the apparent cream volume, as indicated by the cream line, may be reduced by as much as 40 per cent. Prolongation of the pasteurizing period beyond 30 minutes at a temperature of from 142°F. to 145°F. will also proportionately displace the cream line with an apparent decrease in cream volume.

Heating to a pasteurizing temperature does not impair the value of milk as food. The heat may cause a reduction in the vitamin content, but milk need not serve as a principal source of vitamin supply.

There are three recognized processes by which milk is pasteurized commercially. These are pasteurization in-the-bottle, the flash method, and the holding method.

Pasteurization in-the-bottle. Milk may be pasteurized in the bottle in which it is to be delivered to the consumer. In this process, the raw milk is bottled and the bottle so capped or sealed that no water or steam can enter. The contents of the bottle are then subjected to a temperature of not less than 143½°F. for 30 minutes in apparatus designed for that purpose. Pasteurization in-the-bottle has the advantage that recontamination cannot occur subsequent to pasteurization. It has the disadvantage that it is difficult to maintain a uniform pasteurizing temperature in the bottle. As the cost of pasteurization in-the-bottle is considerably greater than that of pasteurization in bulk, this method is rarely used for commercial purposes.

Flash pasteurization. In the flash, or high temperature method of pasteurization, the milk is heated to a temperature of 160°F. or more for not less than 15 seconds in apparatus of approved design and properly operated, and then rapidly cooled. In one apparatus the milk flows continuously between two electric carbons and the electric current heats the milk to 160°F. for the required length of time. The flash method is seldom employed, except in the treatment of milk to be used in the manufacture of milk products.

The holding method of pasteurization. In the holding process, bulk milk is held at a thermometer temperature of not less than 143½°F. for 30 minutes. Pasteurization by this method involves pre-heating the milk to the desired temperature, holding it at a pasteurizing temperature for the prescribed length of time, and rapid cooling to less than 50°F. The holding method is employed in the greater proportion of the commercial milk plants and is the method that should ordinarily be selected for use in plants operated by the army.

Pre-heating. In the process of pasteurization, the milk must be brought to a temperature of 143½°F. before the true pasteurizing period begins. This pre-heating may be effected in the container in which the milk is to be pasteurized, or the milk may be heated to any desired degree in a heating device and then transferred by continuous flow to another container, or holder, for retention at a pasteurizing temperature.

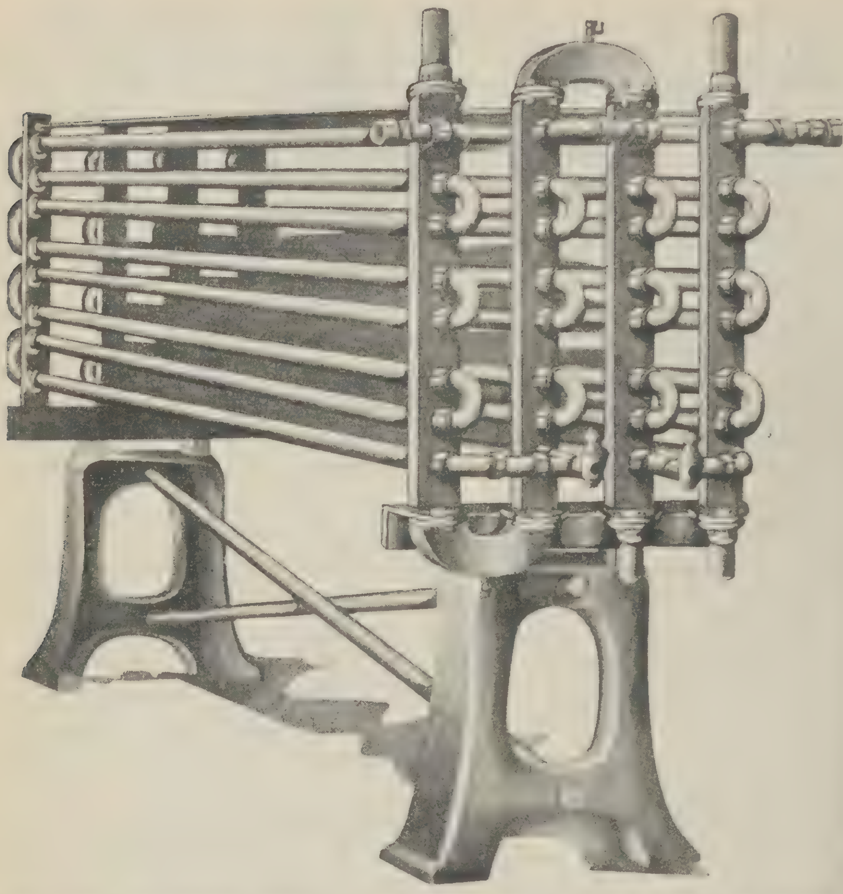


FIG. No. 124. Tubular heater. This apparatus is also used as an internal tubular cooler (*infra*). (Courtesy of the Cherry-Bassett Co., Baltimore, Md.).

The necessity for, or the desirability of, pre-heating the milk in a container separate from that in which the milk is to be pasteurized depends on the arrangement of the plant. The use of continuous flow pre-heaters may, under some circumstances, effect a saving of heat and thus reduce the cost of operation. This method possesses the disadvantage, however, that the milk must come in contact with more surfaces and, therefore, the opportunities for contamination are increased. In many of the larger plants the milk is pre-heated to a pasteurizing temperature in a tubular heater (Fig. No. 124). The

tubular heater consists of a series of double walled pipes so designed that the milk flows through the inner pipes and hot water through the spaces between the inner and outer pipes. The milk and water flow in opposite directions so that a uniform temperature is maintained.

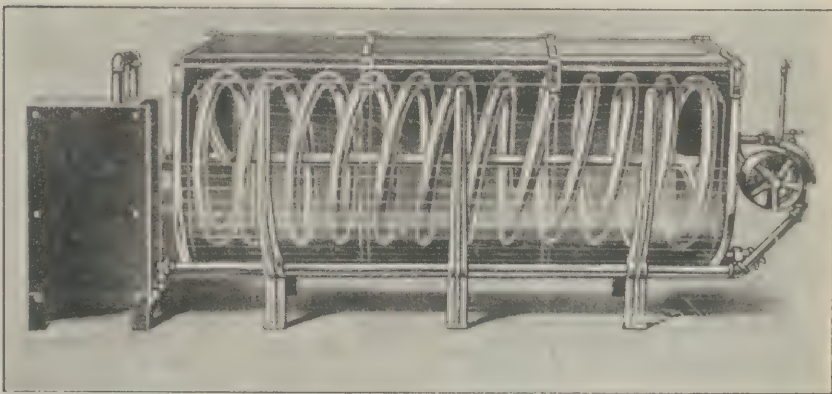


FIG. No. 125. Pasteurizing vat showing horizontal revolving coil through which hot water is forced to maintain a pasteurizing temperature. (Courtesy of the Chester Dairy Supply Co., Chester, Pa.).

In some instances, pre-heating apparatus is equipped with automatic devices operated by thermostatic controls which automatically start or stop the flow of milk into the pasteurizing holder at predetermined temperatures. Such a device may be an automatic milk-pump stop, which stops or starts the milk-pump motor at predetermined milk temperatures, or an automatic flow diversion valve by means of which the flow of milk from the pre-heater is automatically diverted into or away from the holder at predetermined milk temperatures.

Holders. Two general types of apparatus are employed for holding the milk at a pasteurizing temperature for 30 minutes. These are positive or vat holders, and continuous flow holders or retarders. Positive holding is the most common method of pasteurization.

The positive holder retains the milk in the same compartment during the pasteurizing period. In plants equipped with positive holders, the batch method of pasteurization is more commonly employed than any other one method. The milk is placed

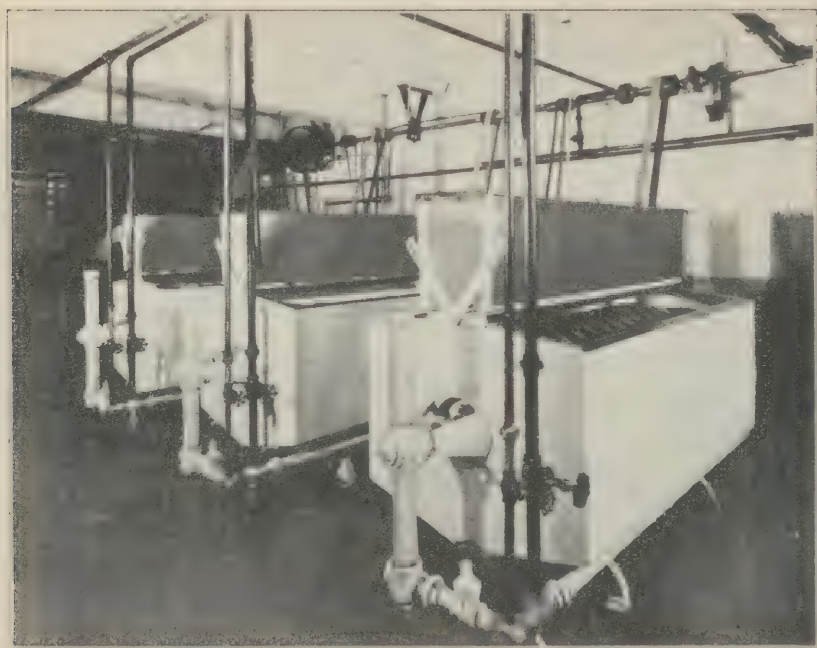


FIG. No. 126. Battery of vat pasteurizers showing coils. (Courtesy of the Creamery Package Manufacturing Co., Chicago, Ill.).

in a vat which serves both as a pre-heater and as a holder for pasteurizing the milk. The capacity of a pasteurizing vat, or batch heater, varies from 100 to 1000 gallons according to the needs of the plant. It is insulated and lined with enamel, glass, or seamless metal (Fig. No. 125). The vat is filled and emptied either by hand or by automatically controlled valves. Automatic control is ordinarily employed where the compartment is separate from the pre-heater, but in the batch system, in which the vat is used as a pre-heater as well as a holder, the valves are usually operated by hand.

Where the batch method is used, the pasteurizing vat is filled with milk from the storage tank or weigh can. The milk in the vat is pre-heated to a temperature of 143½°F. and then held and pasteurized in the vat at a temperature of from 143½°F. to 145°F. As from 15 to 30 minutes are required for the pre-heating process, the entire retention period for pre-heating and pasteurization varies from 45 minutes to one hour.

Where a pre-heater is used, the milk passes from the storage or weigh tank to the pre-heater and then to the pasteurizing vat.

The milk in the vat is usually heated by means of a horizontal revolving coil through which hot water is forced by a pump, air pressure, or gravity (Fig. No. 125). In other types the tank has a surrounding jacket into which live steam is introduced as a heating medium. In the spray type, the vat consists of an inner milk tank which is surrounded by an outer tank. Between the walls of the inner and outer tank is a system of perforated pipes through which hot water is forced and delivered as a spray against the outer sides of the walls of the inner tank. The water then flows down the outer surface of the wall of the inner tank to the bottom of the outer tank to be collected, re-heated and again pumped through the pipe system. The vat is covered to conserve heat and to prevent evaporation and air-borne contamination of the milk.

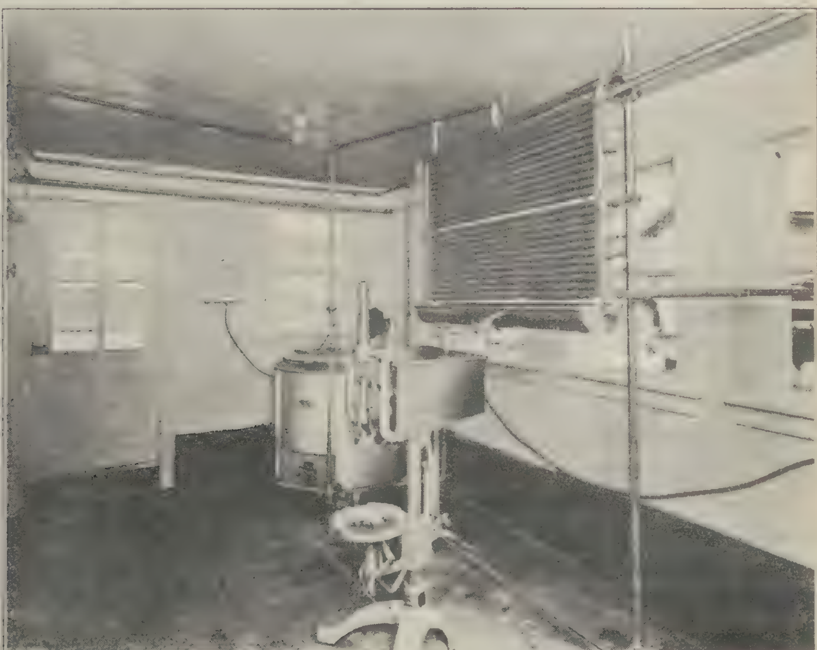


FIG. No. 127. Interior of milk plant showing an upright pasteurizing vat, bottle filler, and uncovered cooler. (Courtesy of the Creamery Package Manufacturing Co., Chicago, Ill.).

In the operation of positive holders, it is essential that all valves be tight so that the milk will not flow in or out of the holder before pasteurization is complete.

The milk may be cooled in the vat, but this is a slow process and usually the milk is drained from the vat to a cooler.

Continuous flow holders or retarders are designed to permit continuous flow of milk through the apparatus, but at such a rate that all the milk is subjected to a temperature of not less than 143½°F. for 30 minutes. The continuous flow holder may consist of a series of pockets, compartments, or vats in which the milk flows from one container to another, or two or more upright tanks may be employed and the milk passed from one tank to another. In another type, the milk is passed through a tubular heater (page 510). In all types of continuous flow holders, the milk passes from the holder to a cooler.

The continuous flow holders have the disadvantage that some of the milk tends to pass through and escape in less than 30 minutes, but good results can be and are obtained with continuous flow holders, if the apparatus is frequently tested for rate of flow and maintenance of a uniform temperature. The rate of flow may be determined by filling the apparatus with water and adding a coloring substance, such as methylene blue, to the water at the entrance to the holder and observing the time required for the color to appear at the outlet.

Control of the pasteurizing process. The efficient operation of a milk plant requires adequate control of each phase of the pasteurizing process from the time the milk is received at the plant until it is delivered to the consumer. Such control can be exercised only when the equipment is properly constructed, installed and operated. Defects in the construction, installation or operation of pasteurizing apparatus increase the opportunities for failure to destroy all pathogenic organisms and for contamination or recontamination of the milk.

Temperature control. Regardless of the type of pasteurizing apparatus employed, some automatic device should be used to control the pasteurizing temperature. Manual control is unreliable, and if employed will from time to time result in sufficient variation in temperature to permit milk to escape unpasteurized.

All plants must be equipped with both indicating and recording thermometers so installed that the temperature of the milk can be readily determined during any stage of the pasteurizing

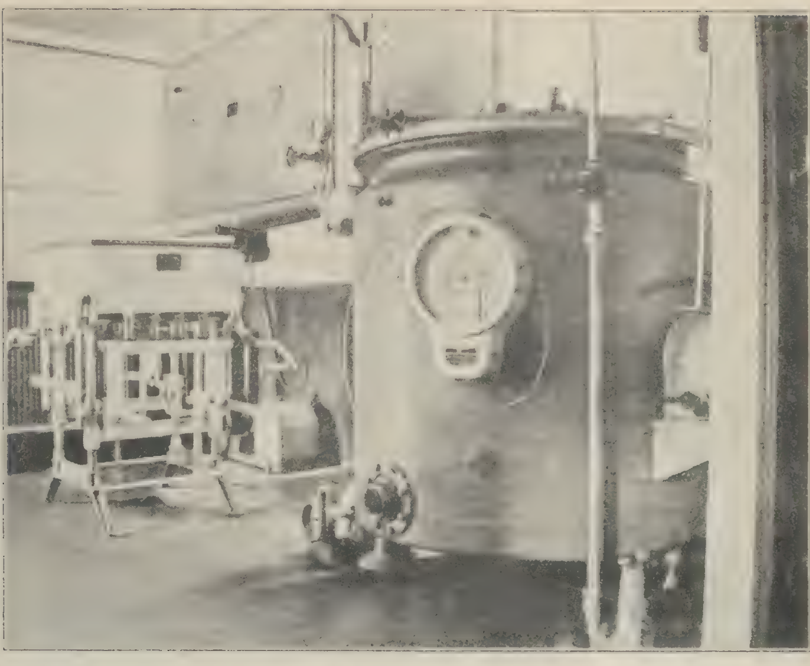


FIG. No. 128. Interior of milk plant showing upright vat pasteurizer, covered cooler and bottle capping apparatus. (Courtesy of the Creamery Package Manufacturing Co., Chicago, Ill.).

process. The pasteurizing process is governed by the indicating thermometer, and the recording thermometer should be frequently checked for accuracy by comparison with the indicating thermometer. The recording thermometers serve to record permanently the temperature maintained during the pasteurizing process, and these records should be available for inspection at any time.

All thermometers should be periodically tested for accuracy against standard instruments.

Structural defects. From a sanitary point of view, the most important of the structural defects in pasteurizing equipment are those which permit a portion of the milk to escape without being subjected to a pasteurizing temperature for the full period of pasteurization.

One of these defects is a cold pocket, which is any recess so located that the milk it contains is not heated to the same degree as the remainder of the milk. Cold pockets are most commonly found in the pipe sections between the holders and the inlet or

the outlet valve, particularly between the holder and the outlet valve. In these pipes, the milk is protected from the heat to an extent which will frequently permit a drop in temperature of 5°F. or more, with the result that the contained milk is not pasteurized.

The usual cold pocket can be eliminated by the installation of valves the seats of which are flush with the inside surface of the holder.

Any valve will, in time, develop a leak due to wearing away of the valve seat. If the inlet valve leaks, raw milk will enter the holder during the holding period and will be discharged from the holder without being completely pasteurized. If the outlet valve develops a leak, unpasteurized milk will escape from the holder into the pipe leading to the cooler during the holding period.

Defective pasteurization due to leaking valves can be prevented by disconnecting the pipe leading to the inlet valve during the heating and holding period, and the pipe leading from the outlet valve during the filling, heating and holding period, or by installation of leak-protector valves. The latter procedure is preferable.

Leak-protector, or leak-escape valves are so constructed that any leakage will escape by a leak port in the bottom of the valve and drain away to waste. A leak-protector valve will prevent leakage into the holder through the inlet valve, or from the holder through the outlet valve into the effluent pipe. It will not, however, prevent leakage from the holder into the outlet valve proper. As the outlet valve may become contaminated in this manner, it should always be disinfected by steaming prior to discharging the holder.

Cold foam. In all positive holders, a certain amount of foam tends to form on the surface of the milk due to the action of the pumps, to the turbulence of the milk while flowing through the inlet pipe and valve, or to the agitation of the milk in the holder. Foaming can be reduced to a minimum by correcting defects in design or operation which permit air to be mixed with the milk. Frequently, a milk pump is so designed or operated that air is pumped with the milk, or air leakage may occur somewhere in the piping. At times foaming is caused by allowing the milk to enter a vat by falling through the air.

Unless the air between the surface of the milk and the cover of the holder is heated by some special means, the temperature of the foam will be less than that of the milk. Consequently, the foam will pass through the holder without being heated to a pasteurizing temperature and will carry contamination into the pasteurized milk.

The temperature of the air above the milk, and the temperature of the foam, may be raised sufficiently to pasteurize the foam by the introduction of steam or hot air between the surface of the milk and the cover of the holder. The temperature of the air above the milk should be at least 5°F. higher than the temperature of the milk, as shown by an indicating thermometer.

Coolers. At the end of the pasteurizing period, the milk should be cooled as rapidly as possible to a temperature of 45°F., or less. Ordinarily either an open surface tubular or an internal tubular cooler is used.

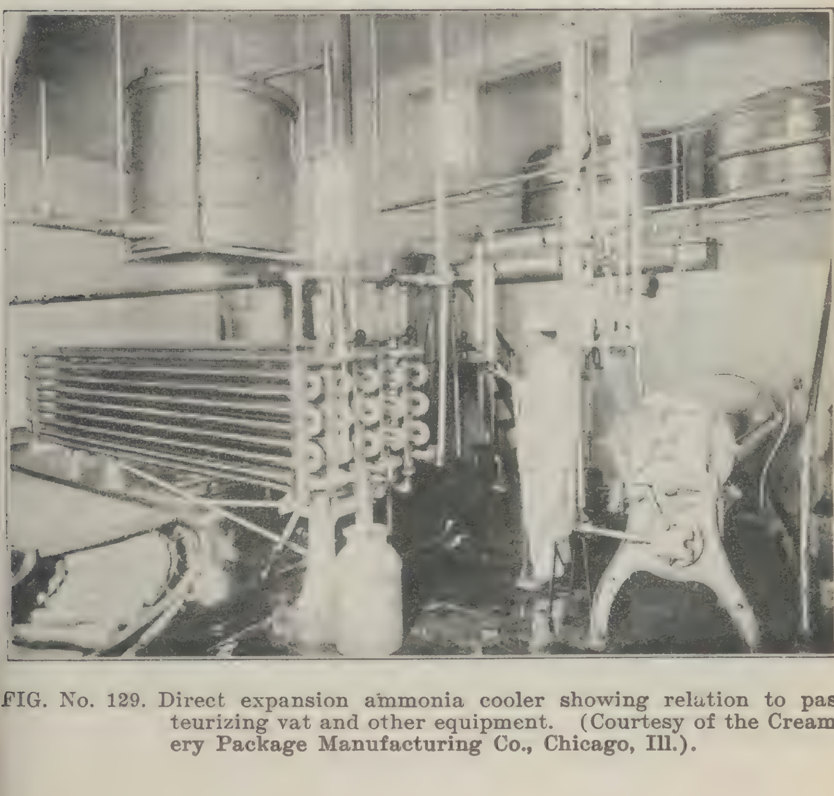


FIG. No. 129. Direct expansion ammonia cooler showing relation to pasteurizing vat and other equipment. (Courtesy of the Creamery Package Manufacturing Co., Chicago, Ill.).

Open surface tubular coolers. The open surface tubular cooler is the most common type. It consists of a series of horizontal tubes, which may be arranged by sections, united at the ends to form a solid unit. The cooling medium passes through the interior of the tubes and the milk flows downward in a thin film over their outer surfaces. The size of the cooler should be such that all the milk will be cooled to the desired temperature by the time it reaches the bottom of the apparatus. Open surface coolers should be covered with a tight fitting shield in order to prevent contamination by dust, flies, by manual contact, or by air-borne infection (Fig. No. 132).

Ice water, brine, or direct-expansion ammonia may be used as a cooling medium. Water may be used exclusively,

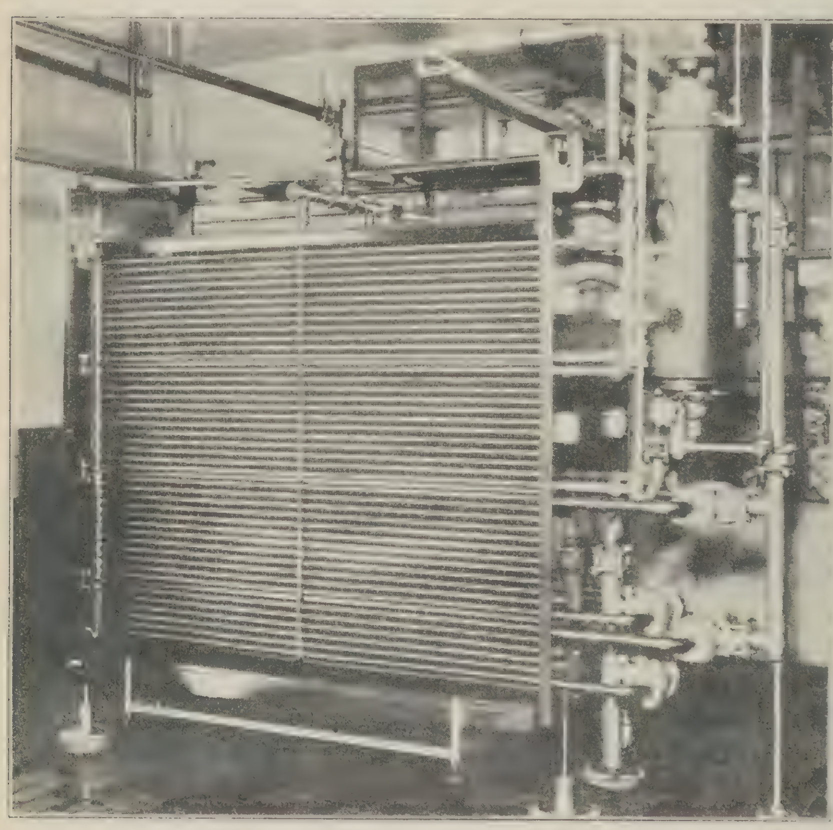


FIG. No. 130. Direct expansion ammonia cooler. (Courtesy of the Creamery Package Manufacturing Co., Chicago, Ill.).

but, usually, the upper sections are cooled with water and the lower with brine or ammonia. Either brine or direct-expansion ammonia is effective for cooling purposes, but the brine method is more commonly employed, particularly in the smaller plants (Figures No. 129 and 130).

Internal tubular cooler. The internal tubular cooler is so constructed that the milk flows through a tube which is enclosed within an outer pipe or jacket containing the cooling medium. The tubes are arranged in coils so that the milk and the cooling liquid flow in opposite directions (Fig. No. 131).

The internal tubular cooler, as compared with the open surface cooler, has the advantage that no evaporation of the milk occurs and all danger of contact with air-borne contamination is prevented. It is more difficult to clean and disinfect than the open surface cooler.

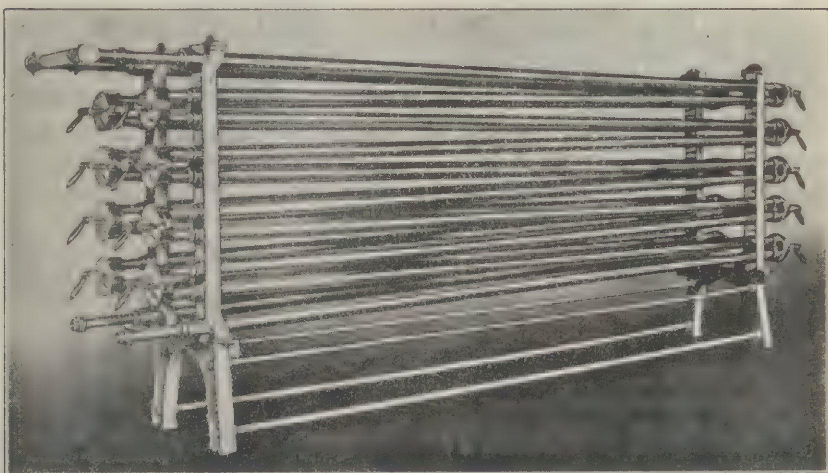


FIG. No. 131. Internal tubular cooler. (Courtesy of the Chester Dairy Supply Co., Chester, Pa.).

Bottling and capping. The milk as it comes from the cooler is immediately bottled and the bottles capped and stored in refrigerators or cold storage rooms, or prepared for delivery (Fig. No. 132).

As a rule, the bottles are filled and capped by machines. The equipment used for this purpose should in all instances be of such nature and so arranged and operated as to obviate

all danger of recontamination of the pasteurized milk. All caps should be purchased and subsequently handled in sanitary tubes. Under no circumstances should caps be permitted to come in contact with the hands.

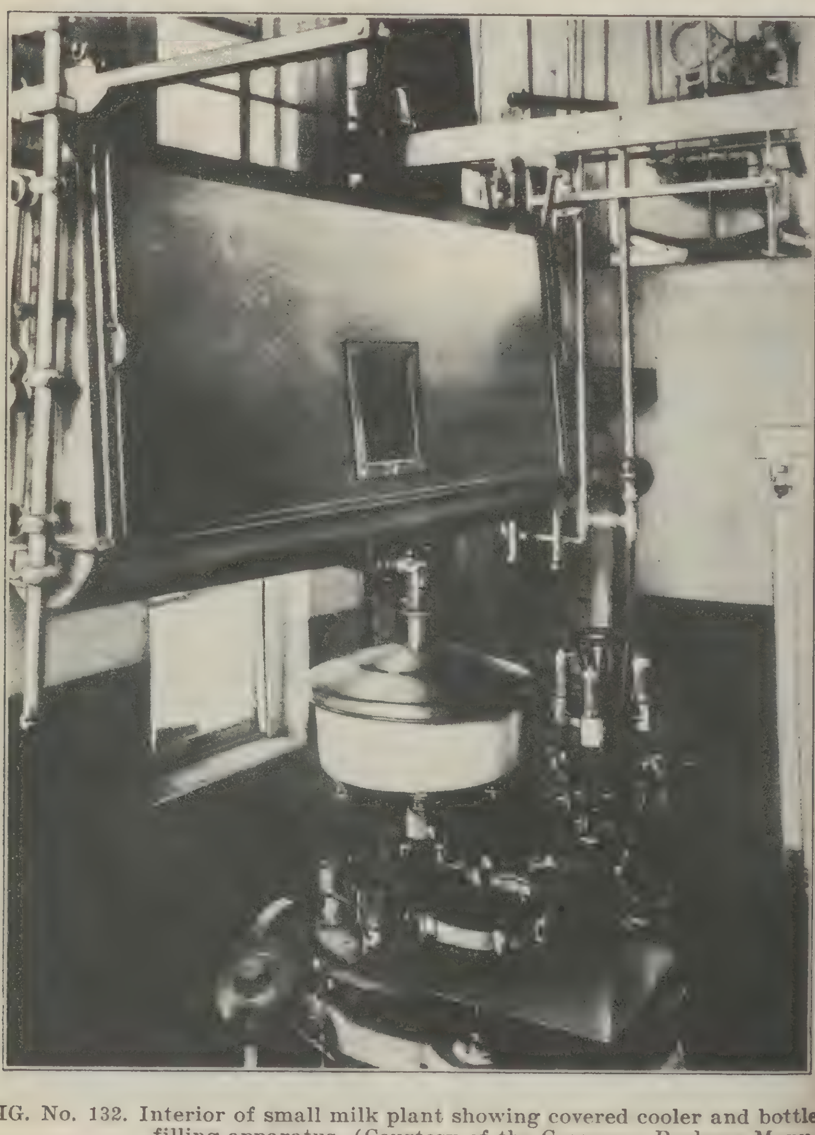


FIG. No. 132. Interior of small milk plant showing covered cooler and bottle filling apparatus. (Courtesy of the Creamery Package Manufacturing Co., Chicago, Ill.).

Hand operated bottle fillers and cappers. The hand operated milk bottle filler consists of a tank equipped with a series of filling valves at one or both ends. Some of the machines have four valves at one end of the tank, while others have four at one end and five at the other. The standard quart bottle case contains four bottles in a row, while the pint bottle case has five in a row. The valves are arranged to permit filling the bottles without removing them from the case. Some of the larger machines are designed to fill a case of bottles at one operation. The machine is operated by means of a hand lever which raises a row of bottles until they press against and lift the valves, releasing a flow of milk into the bottles below. When filled, the bottles are capped with a hand operated capping machine.

Automatic filling and capping machines. Most of the larger plants are equipped with automatic fillers and cappers. The most common type is the rotary filler and capper. The machine consists of a tank equipped with filling valves under which there is a revolving carrier. The bottles are placed singly on the carrier which conducts them under the valves. Each bottle is automatically raised and held against the valve and filled with milk while it travels around the machine. It is then automatically lowered and carried to an automatic capping machine (Figures No. 132 and 133).

In another type of automatic filler and capper, the bottle case passes through the machine and the bottles are filled and capped without being removed from the case.

Cleansing and disinfection of milk bottles. The bottles returned to the milk plant must be cleaned and disinfected before being refilled. Hand washing may be practiced in small plants, but it is, as a rule, an ineffective method and will usually fail to disinfect some of the bottles. Generally, milk plants are equipped with automatic or semi-automatic bottle washers.

Semi-automatic and automatic bottle washing machines. The simplest form of a bottle washing machine is one in which the bottles are washed by a power driven revolving brush. After being washed the bottles are inverted in the bottle case and disinfected with hot water or steam. Usually, disinfection is effected by placing the inverted bottles over valves through which jets of hot water or steam are pumped or released into the bottles.

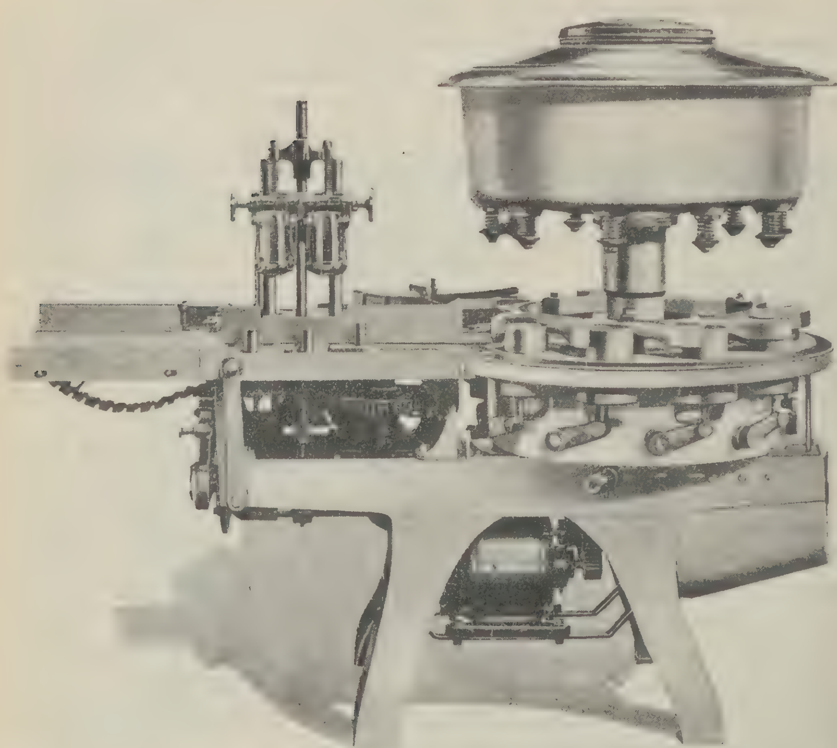


FIG. No. 133. Automatic bottle filling and capping machine. (Courtesy of the Chester Dairy Supply Co., Chester, Pa.).

Automatic power washers, which are more commonly used by the larger plants, vary considerably in structural and mechanical details, but, in general, the bottles are washed, rinsed and disinfected by jets of hot alkaline solution, hot water and steam. The bottles may be passed through the machine singly or in cases and are usually fed into one end of the machine and taken out at the other end, or passed through the lower part of the machine and back through the upper part to the end at which they entered. As the bottles are carried through the machine, they pass successively over jets of alkaline solution, hot water and steam. In some types of washers, revolving brushes pass upward into the inverted bottles. If the washer is properly operated, the bottles leave the machine clean and free from contamination (Fig. No. 135).

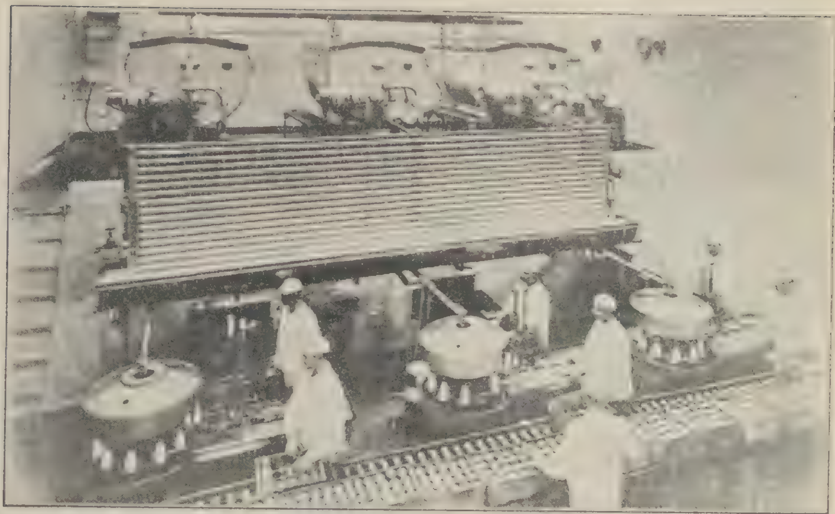


FIG. No. 134. Pasteurizing vats, surface cooler and filling and capping machines. (Courtesy of the Bureau of Dairy Industry, U.S. Dept. of Agriculture, Washington, D. C.).

FIG. No. 135. Bottle washer, six bottles wide. (Courtesy of the Creamery Package Manufacturing Co., Chicago, Ill.).

Use of chlorine solutions. Solutions containing free chlorine may be used in lieu of steam in the disinfection of milk bottles. The chlorine is added to the rinse water in proportion of not less than 50 parts per million of free chlorine (page 526). If the bottles are washed by hand or with a revolving brush machine, they are disinfected by submersion in rinse water containing

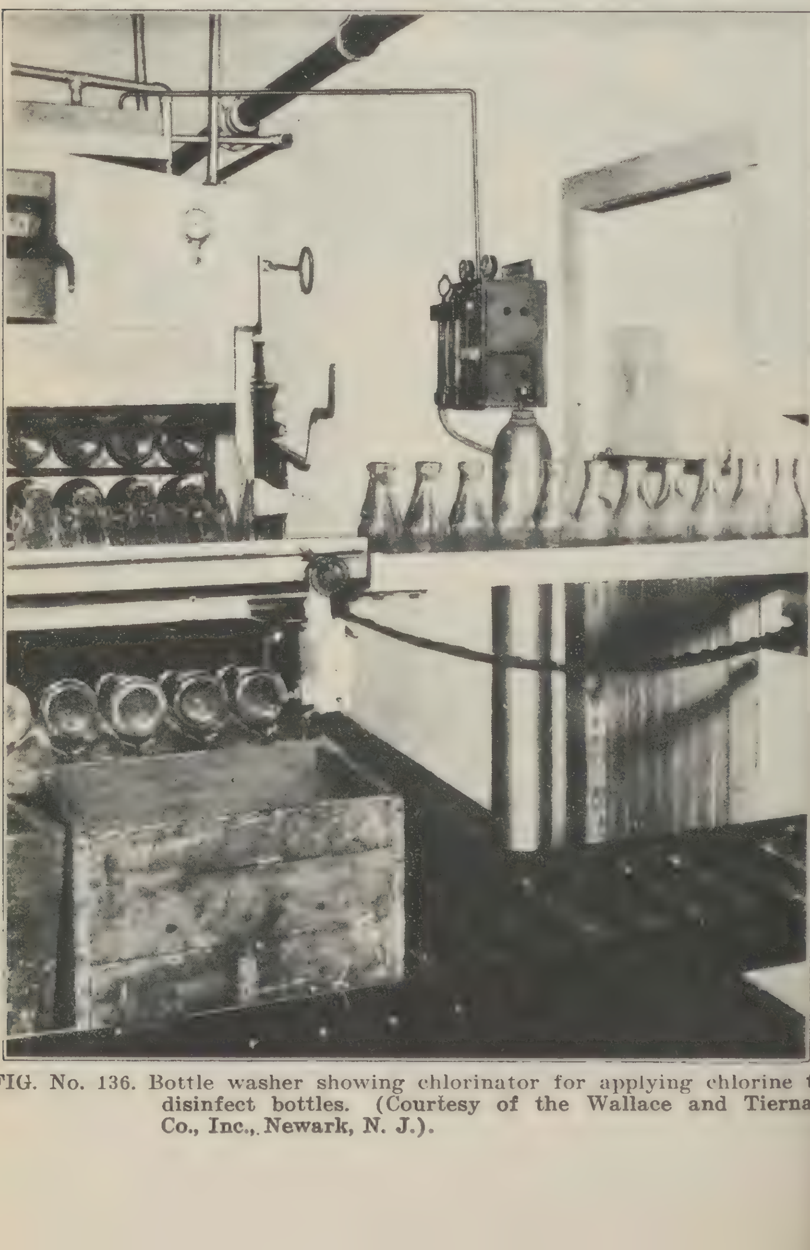


FIG. No. 136. Bottle washer showing chlorinator for applying chlorine to disinfect bottles. (Courtesy of the Wallace and Tiernan Co., Inc., Newark, N. J.).

chlorine. If a power driven washer is used, the bottles are sprayed on the inside with the chlorinated water by passing the inverted bottles over jets or perforated plates through which the spray is forced by a pump. This is an effective method of disinfecting bottles (Fig. No. 136).

Inspection of milk bottles. All milk bottles should be inspected before being passed through an automatic washing machine. A few of the bottles returned to the plant will contain dried milk substances which cannot be removed from the sides and bottom of the bottle by the washing machine. These bottles should be washed by hand, or soaked in an alkaline solution, before being placed in the washing machine.

All bottles should be inspected for cleanliness both before and after filling with milk. Frequently small particles of dirt will be more apparent in the filled than in the empty bottle. All bottles showing any visible dirt should be returned for re-washing.

Cleansing and disinfection of milk plant equipment. High bacterial counts or the rapid souring or spoilage of pasteurized milk are frequently due to dirty apparatus and not to operating defects concerned with the pasteurizing process proper. Further, such contamination may result from an apparently insignificant error in the cleaning and disinfecting process, such as, for example, failure to disinfect a union or elbow in the effluent piping. Milk is an excellent culture medium and the temperature in many parts of the apparatus is favorable for the growth of micro-organisms. Under these conditions, bacteria will grow rapidly and luxuriantly in any contaminated crevices or recesses.

Methods of cleaning and disinfecting. All parts of the pasteurizing equipment with which the milk comes in contact should be thoroughly cleaned and disinfected after use. Generally, cool or tepid water should be passed through all the apparatus, followed by a hot solution of washing powder. All pumps and pipes should then be taken apart and cleaned with hot water containing washing powder (an alkaline solution) and rinsed with clear, hot water. Great care should be taken that all joints or unions are thoroughly cleaned and disinfected, using a hand brush if necessary.

After cleaning, all apparatus should be disinfected with steam. Wherever steam is used as a disinfecting agent, either in

piping or by application to open surfaces, it should be applied for at least two minutes.

Vat or pocket holders should be cleaned by first rinsing to remove the milk film, followed by washing with hot water and washing powder, and disinfected with steam. Hand brushes should be used to insure the cleansing of all parts of the holder.

Particular attention should be given to the cleaning and disinfection of the cooler and the effluent piping of the holder and cooler. These parts at least should be again disinfected shortly before using. If the milk is contaminated after pasteurization, the organisms will not be destroyed by any of the subsequent procedures and will remain in the milk delivered to the consumer.

The open surface cooler should be disinfected with a steam jet from a steam hose line or a steam pipe immediately after use and again just prior to being put in operation.

If steam is not available, disinfection can be effected by hot water or chlorine solutions. If hot water is used it should be applied for not less than two minutes. The temperature of the water should be at least 170°F. throughout the entire disinfection period. Where piping is disinfected by hot water, the temperature of the water should be 170°F. or higher where it flows from the pipe.

Where a chlorine solution is employed as a disinfecting agent it should contain at least 50 parts per million of free chlorine at all times while being used as a disinfectant. A chlorine solution containing approximately 100 parts per million of free chlorine is made by adding two ounces of calcium hypochlorite containing 33 per cent of available chlorine, or one ounce of Grade A calcium hypochlorite (page 292), to fifty gallons of water. If greater or less quantities of the solution are to be made the amount of chemical used is varied accordingly. The dry calcium hypochlorite should be mixed with a small amount of water to form a paste. The paste is then thoroughly mixed with sufficient water to make a solution having the desired strength. The chlorine solution should be applied for a period of at least five minutes.

The strength of a chlorine solution can be determined by the orthotolidine test (page 313). One c.c. of the solution to be tested is diluted with 99 c.c. of water containing no chlorine, and from ten to fifteen drops of the orthotolidine solution are

added. The color produced is compared with a standard (page 313).

A simple test for available chlorine content of a disinfecting solution which may be used by an inspector at a farm or at a milk plant has been devised by the office of milk investigations of the United States Public Health Service. The sample of the solution to be tested is diluted to two-fifths of its original strength by adding three c.c. of chlorine free water to two c.c. of the solution. A test tube etched at the two c.c. and the five c.c. levels should be used. One drop of the orthotolidine solution is added to the dilute sample in the test tube and the lower end of the test tube tapped sharply about 50 times. If, in the case of hypochlorites, a reddish or brownish precipitate settles out within five minutes, the original solution contains at least 50 p.p.m. of available chlorine. In some plants a chloramine compound is used instead of calcium hypochlorite. If the test solution becomes cloudy the chloramine content of the original solution is equivalent, in bactericidal power after a two-minute exposure, to at least 50 p.p.m. of available chlorine in the form of hypochlorite.

Control of thermophilic bacteria. Certain of the thermophilic bacteria have an optimum temperature of about 145° F. and consequently grow freely in milk at pasteurizing temperatures. Raw milk does not ordinarily contain any considerable number of thermophilic organisms, particularly if it has been properly cooled. The development of thermophiles in pasteurized milk is usually due to poor operating conditions at the milk plant which result in prolongation of the pasteurizing period, delayed or inadequate cooling of milk subsequent to pasteurization, or failure to clean and disinfect the pasteurizing equipment. Where the hot milk is filtered, the filter cloths may be a source of contamination if the same cloths are used for several days. Thermophiles may be introduced into a milk supply by repasteurization of previously pasteurized milk.

The development of large numbers of thermophilic organisms can be prevented by thorough cleansing and disinfection of all pasteurizing apparatus, and by prompt cooling after pasteurization. If a milk supply is heavily contaminated with thermophiles, positive holders should be disinfected after each pasteurizing period. Continuous flow holders should, under the same conditions, be disinfected at intervals of from one to two hours during the operation of the plant. If the hot

milk is filtered, the filter cloths should be changed at intervals of two or three hours.

As far as is known, none of the thermophilic bacteria are pathogenic. However, their presence in any considerable numbers in pasteurized milk is an indication of faulty methods which might render the milk potentially unsafe. The conditions which permit the development of thermophiles should be determined by inspection and corrected. If such conditions are not corrected, it is generally advisable to reject the milk for use by troops.

Cleansing of milk cans. All milk cans in which milk is received should be washed, disinfected and dried at the pasteurizing plant. If this is not done, any failure to disinfect the cans at the farm where the milk is produced will tend to increase greatly the contamination of the raw milk.

Can washing methods. In the smaller plants, the cans may be washed with a hand brush and a hot solution of washing powder, followed by disinfection over a steam jet which forces live steam into the can. The steam should be applied for at least two minutes in order to effect disinfection and to promote rapid drying.

Can washing machines are employed in the larger plants (Fig. No. 123). In general, these machines are designed to carry the inverted cans successively over powerful jets of hot washing powder solution, hot rinsing water, and steam. The can covers must also be cleaned and disinfected.

Hot water or a chlorine solution may be used instead of steam to disinfect cans (*supra*).

It is essential that the cans be quickly and thoroughly dried. Usually, the heat in the metal after steaming is sufficient to dry the can in a satisfactory manner, but some machines provide a blast of hot air for drying purposes. As soon as the can is dry, the cover should be put in place to prevent recontamination.

Installation of equipment. From a sanitary point of view, milk plant equipment must be installed so that the milk will flow through the plant without receiving additional contamination prior to pasteurization and without being subsequently recontaminated. In order to meet this requirement, the equipment should be arranged so that there is a continuous flow, without additional handling, from the weigh tank or storage tank to the bottle in which the milk is to be delivered to the

consumer. This may be accomplished by gravity alone or with the aid of one or more pumps (Fig. No. 134).

Arrangement of equipment. In a typical plant using the holding method of pasteurization, the milk passes from the weigh tank through the clarifier, pasteurizing vat, cooler, filler and capper in the order named. Where other apparatus is employed, such as a pre-heater, or a storage tank for the cooled milk, the arrangement of the equipment and the flow of the milk through the plant are varied accordingly.

Usually, the flow of milk through the plant is effected partly by gravity, and partly by pumping. Gravity alone may be employed, but this is not a common method.

Storage and delivery of pasteurized milk. From a sanitary viewpoint, the precautions to be taken in the storage and delivery of pasteurized milk are concerned with preventing the multiplication of organisms which have not been destroyed by the pasteurizing process. This is done by keeping the milk at a low temperature from the time it leaves the cooler until it is delivered to the consumer.

Pasteurized milk which is not intended for immediate delivery should be stored in refrigerators or cold storage rooms at a temperature of from 40°F. to 48°F. In many plants, the milk is pasteurized on one day and held for delivery on the next day. In the operation of these plants, the milk bottles should be taken directly from the filling and capping machine to the cold storage room.

The temperature of the milk should not be more than 50°F. when delivered to the consumer. The milk in the delivery trucks should be iced in order to maintain the desired temperature until delivery.

The milk may be delivered from the pasteurizing plant directly to the consumer or to milk stores. If delivered to a milk store, refrigerating facilities should be available at the store.

General sanitation of milk plants. Cleanliness throughout is essential in the operation of a milk plant, and this applies to all parts of the plant from the receiving platform to the delivery wagons. The walls and floor should be constructed of non-absorbent material to facilitate washing with water under pressure, scrubbing, and the use of steam. All milk plants

should have an ample supply of safe water and steam for cleansing and disinfecting purposes.

Ventilation. A fundamental principle of milk plant ventilation is the adequate interchange of the indoor and outdoor air without the production of drafts and without introducing dust or flies into the rooms of the plant. The arrangement of the plant is frequently such that natural ventilation by means of windows is difficult to obtain. In some plants, good ventilation is secured by the proper use of windows and exhaust ducts, while in others it is necessary to install some form of mechanical ventilation. The incoming air may be filtered through several layers of cheesecloth in order to exclude dust. In warm climates, or in the warm seasons of the year, it may be found desirable to cool the air by passage over brine or ammonia coils before it enters the plant.

Natural ventilation cannot be utilized in cold storage rooms, and such rooms should be provided with some system of artificial ventilation. Poor ventilation interferes with cooling and promotes the condensation of moisture on the contents of the cold storage room and on the ceiling and walls.

Fly control. All doors and windows, ventilator shafts, or other openings, should be screened and the screening kept in good repair. All screen doors should be of the self-closing type. All house flies which gain entrance to the interior of the building should be immediately killed with swatters or by fly paper or fly wires (Chapter XVIII).

Personnel. All milk handlers should be physically examined for the purpose of detecting any who may be carriers of a communicable disease (page 588). This examination should be made prior to employment and periodically thereafter at intervals of not more than twelve months. In the case of government owned plants, milk handlers should be examined at intervals of not more than six months. No person found to be a carrier of a communicable disease should be employed, or continued in the employ of a milk plant.

The physical examination of the employees of a civilian owned plant is conducted by a civilian physician. The men detailed for duty or employment in a milk plant operated by the army are examined by a medical officer. The examiner should issue a certificate to those workers found to be free

from communicable disease, and a record of all examinations should be kept available for inspection at the plant.

All milk handlers should be observed daily by the operator of the plant and no one who shows signs of being ill, especially with a respiratory or an intestinal disease, should be permitted to continue work, or to resume work until all symptoms have disappeared.

Cleanliness. All milk handlers should be required to maintain a high degree of personal cleanliness. Sanitary lavatory and toilet facilities should be provided for the employees. The hands should be kept clean at all times and the rule that the hands must be washed in hot soapy water after visiting the toilet should be strictly enforced.

Suits of clean, washable outer clothing and caps should be provided for all milk handlers to wear while at work and this clothing should be stored in a clean, dust free place when not in use. The suits and caps should be white in color so that dirty clothing can be readily detected.

In the operation of all milk plants, rules should be promulgated and enforced which will prevent expectoration, coughing and sneezing in such a manner as to contaminate the milk, or the apparatus or utensils used in handling the milk.

GRADING OF MILK

It is customary for civilian health authorities to grade the milk which is to be sold to the public according to certain recognized standards based on bacterial content and the observance of minimum sanitary requirements. The standards for each grade, particularly the sanitary standards which must be observed during the production of the milk, vary somewhat in different communities, but those provided for in the "Standard Milk Ordinance", U. S. Public Health Service, represent the average minimum requirements. Where milk subject to grading by local civilian authorities is to be purchased for issue to the troops, the laws and regulations governing the grading of the milk, and the extent to which they are enforced, should be investigated by a Medical Department officer.

The Standard Milk Ordinance, U.S. Public Health Service.

(*Extracts*)

* * * * * * *

Average bacterial plate count, reduction time, and cooling temperature. Average bacterial plate count shall be taken to mean the logarithmic average of the bacterial plate counts of the last four consecutive samples, taken upon separate days, irrespective of periodic grade announcements. Average reduction time shall be taken to mean the arithmetical average of the reduction times of the last four consecutive samples, taken upon separate days, irrespective of periodic grade announcements. Average cooling temperature shall be taken to mean the arithmetical average of the temperatures of the last four consecutive samples, taken upon separate days, irrespective of periodic grade announcements.

Grading period. The grading period shall be such period of time as the health officer may designate within which grades shall be determined for all milk and/or milk products, provided that the grading period shall in no case exceed 6 months.

Inspection of dairy farms and milk plants for the purpose of grading or regrading. At least once during each grading period the health officer shall inspect all dairy farms and all milk plants whose milk or milk products are intended for consumption within the city of...... or its police jurisdiction. In case the health officer discovers the violation of any item of sanitation, he shall make a second inspection after a lapse of such time as he deems necessary for the defect to be remedied, but not before the lapse of 3 days, and the second inspection shall be used in determining the grade of milk and/or milk products. Any violation of any item of this ordinance on two consecutive inspections within any one grading period shall call for immediate degrading.

The examination of milk and milk products. During each grading period at least four samples of milk and/or cream from each dairy farm and each milk plant shall be taken on separate days and examined by the health officer. Samples of other milk products may be taken and examined by the health officer as often as he deems necessary. Samples of milk and/or milk products from stores, cafes, soda fountains, restaurants, and other places where milk or milk products are sold shall be examined as often as the health officer may require. Bacterial plate counts shall be made in conformity with the latest standard methods recommended by the American Public Health Association. Examinations may include such other chemical and physical determinations as the health officer may deem necessary for the detection of adulteration, these examinations to be made in accordance with the latest standard methods of the American Public Health Association and the Association of Official Agricultural Chemists. Bacterial plate count, reductase test, and cooling temperature results shall be given to the producer or distributor concerned as soon as determined if said results fall without the limits prescribed for the grade then held. Samples may be taken by the health officer at any time prior to the

final delivery of the milk or milk products. All proprietors of stores, cafes, restaurants, soda fountains, and other similar places shall furnish the health officer, upon his request, with the name of the distributor from whom their milk and/or milk products are obtained.

The grading of milk and milk products. At least once every 6 months the health officer shall announce the grades of all milk and milk products delivered by all producers or distributors and ultimately consumed within the city of ...., or its police jurisdiction. Said grades shall be based upon the following standards, the grading of milk products being identical with the grading of milk except that the bacterial standards shall be doubled in the case of cream, and omitted in the case of sour cream, buttermilk, and cultured buttermilk. Vitamin D milk shall be only of grade A or grade B pasteurized, certified, or grade A raw quality.

Grade A raw milk. Grade A raw milk is milk the average bacterial plate count of which does not exceed 50,000 per cubic centimeter or the average reduction time of which is not less than 8 hours, and which is produced upon dairy farms conforming with all of the following items of sanitation.

(1) *Cows; tuberculosis, and other diseases.* A physical examination and, except as provided hereinafter, a tuberculin test of all herds and additions thereto shall be made before any milk therefrom is sold, and at least once every 12 months thereafter, by a licensed veterinarian approved by the State livestock sanitary authority. Said tests shall be made and any reactors disposed of in accordance with the requirements approved by the United States Department of Agriculture, Bureau of Animal Industry, for accredited herds.

A certificate signed by the veterinarian or attested to by the health officer, and filed with the health officer, shall be evidence of the above test.

Provided that in modified accredited counties the modified accredited area system approved by the United States Bureau of Animal Industry shall be accepted in lieu of annual testing.

For diseases other than tuberculosis such tests and examinations as the health officer may require shall be made at intervals and by methods prescribed by him, and any diseased animals or reactors shall be disposed of as he may require.

(2) *Dairy barn, lighting.* A dairy milking barn shall be required, and in such sections thereof where cows are milked windows shall be provided and kept clean and so arranged as to insure adequate light properly distributed, and when necessary shall be provided with adequate supplementary artificial light.

(3) *Dairy barn, air space and ventilation.* Such sections of all dairy barns where cows are kept or milked shall be well ventilated and shall be so arranged as to avoid overcrowding.

(4) *Dairy barn, floors.* The floors and gutters of such parts of all dairy barns in which cows are milked shall be constructed of concrete or other approved impervious and easily cleaned material, shall be graded to drain properly, and shall be kept clean and in good repair. No

horses, pigs, fowl, calves, etc., shall be permitted in parts of the barn used for milking.

(5) *Dairy barn, walls and ceilings.* The walls and ceilings of all dairy barns shall be whitewashed once each year or painted once every 2 years, or oftener if necessary, or finished in an approved manner, and shall be kept clean and in good repair. In case there is a second story above that part of the barn in which cows are milked, the ceiling shall be tight. If the feed room adjoins the milking space, it shall be separated therefrom by a dust-tight partition and door. No feed shall be stored in the milking portion of the barn.

(6) *Dairy barn, cow yard.* All cow yards shall be graded and drained as well as practicable and kept clean.

(7) *Manure disposal.* All manure shall be removed and stored or disposed of in such manner as best to prevent the breeding of flies therein or the access of cows to piles thereof.

(8) *Milk house or room, construction.* There shall be provided a milk house or milk room for the cooling, handling, and storage of milk and/or milk products and the washing, bactericidal treatment, and storage of milk apparatus and utensils. The milk house or room (a) shall be provided with a tight floor constructed of concrete or other impervious material, in good repair, and graded to provide proper drainage; (b) shall have walls and ceilings of such construction as to permit easy cleaning, and shall be well painted or finished in an approved manner; (c) shall be well lighted and ventilated; (d) shall have all openings effectively screened including outward-opening self-closing doors, unless other effective means are provided to prevent the entrance of flies; and (e) shall be used for no other purposes than those specified above except as may be approved by the health officer, shall not open directly into a stable or into any room used for domestic purposes, shall have water piped into it, shall be provided with adequate facilities for the heating of water for the cleaning of utensils, shall be equipped with stationary wash and rinse vats, which, in the case of retail raw milk, if chlorine is employed as the principal bactericidal treatment, shall be of the 3-compartment type, and shall be partitioned to separate the handling of milk and the storage of cleansed utensils from the cleaning and other operations, which shall be so located and conducted as to prevent any contamination of the milk or of cleaned equipment.

(9) *Milk house or room, cleanliness and flies.* The floors, walls, ceilings, and equipment of the milk house or room shall be kept clean at all times. All means necessary for the elimination of flies shall be used.

(10) *Toilet.* Every dairy farm shall be provided with one or more sanitary toilets conveniently located, and properly constructed, operated, and maintained so that the waste is inaccessible to flies and does not pollute the surface soil or contaminate any water supply.

(11) *Water supply.* The water supply for the milk room and dairy barn shall be properly located, constructed, and operated, and shall be easily accessible, adequate, and of a safe, sanitary quality.

(12) *Utensils, construction.* All containers or other utensils used in the handling, storage, or transportation of milk or milk products must be made of nonabsorbent material and of such construction as to be easily cleaned, and must be in good repair. Joints and seams shall be soldered flush. All milk pails shall be of a small-mouth design approved by the health officer.

(13) *Utensils, cleaning.* All containers, equipment, and other utensils used in the handling, storage, or transportation of milk and milk products must be thoroughly cleaned after each usage.

(14) *Utensils, bactericidal treatment.* All containers, equipment, and other utensils used in the handling, storage, or transportation of milk or milk products shall between each usage be subjected to an approved bactericidal process with steam, hot water, or chlorine.

(15) *Utensils, storage.* All containers and other utensils used in the handling, storage, or transportation of milk or milk products shall be stored so as not to become contaminated before again being used.

(16) *Utensils, handling.* After bactericidal treatment no container or other milk or milk product utensil shall be handled in such manner as to permit any part of any person or his clothing to come in contact with any surface with which milk or milk products come in contact.

(17) *Milking, udders and teats, abnormal milk.* The udders and teats of all milking cows shall be clean at the time of milking. Abnormal milk shall be kept out of the milk supply and so handled and disposed of as to preclude the infection of the cows and the contamination of the milk utensils.

(18) *Milking, flanks.* The flanks, bellies, and tails of all milking cows shall be free from visible dirt at the time of milking.

(19) *Milkers' hands.* Milkers' hands shall be clean, rinsed with a bactericidal solution, and dried with a clean towel, immediately before milking and following any interruption in the milking operation. Wet-hand milking is prohibited. Convenient facilities shall be provided for washing of milkers' hands.

(20) *Clean clothing.* Milkers and milk handlers shall wear clean outer garments while milking or handling milk, milk products, containers, utensils, or equipment.

(21) *Milk stools.* Milk stools shall be kept clean.

(22) *Removal of milk.* Each pail of milk shall be removed immediately to the milk house or straining room. No milk shall be strained or poured in the dairy barn.

(23) *Cooling.* Milk must be cooled within 1 hour after completion of milking to 50°F. or less, and maintained at that average temperature until delivery. If milk is delivered to a milk plant or receiving station for pasteurization or separation, it must be delivered within 2 hours after completion of milking or cooled to 50°F. or less and maintained at that average temperature until delivered.

(24) *Bottling and capping.* Milk and milk products shall be bottled from a container with a readily cleanable valve, or by means of an approved bottling machine. Bottles shall be capped by machine.

The bottler and capper shall be cleaned and subjected to bactericidal treatment before each usage. Caps shall be purchased in sanitary containers and kept therein in a clean dry place until used.

(25) *Personnel, health.* Every person connected with a retail raw dairy whose work brings him in contact with the production, handling, storage, or transportation of milk, milk products, containers, or equipment shall furnish such information, permit such physical examinations, and submit such laboratory specimens as the health officer may require for the purpose of determining freedom from infection.

The health officer, or a physician authorized by him, shall in each such instance take a careful history and if such history suggests that such person may be a carrier of or infected with the organisms of typhoid or paratyphoid fever or of any other communicable disease likely to be transmitted through milk, he shall secure appropriate specimens of bodily discharges and cause them to be examined in a laboratory approved by him or by the State health authorities for such examinations.

(26) *Miscellaneous.* All vehicles used for the transportation of milk or milk products shall be so constructed and operated as to protect the milk or milk products from the sun and from contamination. Such vehicles shall be kept clean, and no substance capable of contaminating milk or milk products shall be transported with milk or milk products in such manner as to permit contamination. All vehicles used for the distribution of milk or milk products shall have the name of the distributor prominently displayed.

The immediate surroundings of the dairy shall be kept in a neat, clean condition.

Grade B raw milk. Grade B raw milk is milk the average bacterial plate count of which at no time prior to delivery exceeds 200,000 per cubic centimeter, or the average reduction time of which is not less than 6 hours, and which is produced upon dairy farms conforming with all items of sanitation required for grade A raw milk except as follows: Under item 4 above tight wooden floors and gutters shall be permitted in place of concrete; under item 5 above painting or whitewashing shall not be required; under item 8 above the piping of water into the milk house, the partitioning of processes, and the provision of stationary and three-compartment wash and rinse vats shall not be required; under item 23 above the temperature requirement of retail raw milk shall be 60°F. and of milk for pasteurization or separation 70°F.; item 25 above shall not be required; under item 26 above covered vehicles shall not be required; provided that all items or parts of items relating to cleanliness shall be required.

Grade C raw milk. Grade C raw milk is milk the average bacterial plate count of which at no time prior to delivery exceeds 1,000,000 per cubic centimeter, or the average reduction time of which is not less than 3½ hours, and which is produced upon dairy farms conforming with all items of sanitation required for grade B raw milk except items 7, 12, 20, 21, 22, 23, 24, and 26 above; provided that under item

4 properly constructed clay-mixture floors shall be permitted, and that under item 5 tight ceilings and feed rooms shall not be required.

Grade D raw milk. Grade D raw milk is milk which does not meet the requirements of grade C raw milk, and which shall be plainly labeled "cooking only."

Pasteurized milk. Grade A pasteurized milk is grade A or grade B raw milk which has been pasteurized, cooled, and bottled in a milk plant conforming with all of the following items of sanitation and the average bacterial plate count of which at no time after pasteurization and until delivery exceeds 30,000 per cubic centimeter.

(1) *Floors.* The floors of all rooms in which milk or milk products are handled or stored shall be constructed of concrete or other equally impervious and easily cleaned material and shall be smooth, properly drained, provided with trapped drains, and kept clean.

(2) *Walls and ceilings.* Walls and ceilings of rooms in which milk or milk products are handled or stored shall have a smooth, washable, light-colored surface and shall be kept clean.

(3) *Doors and windows.* Unless other effective means are provided to prevent the access of flies, all openings into the outer air shall be effectively screened and doors shall be self-closing.

(4) *Lighting and ventilation.* All rooms shall be well lighted and ventilated.

(5) *Miscellaneous protection from contamination.* The various milk-plant operations shall be so located and conducted as to prevent any contamination of the milk or of the clean equipment. All means necessary for the elimination of flies shall be used. This requirement shall be interpreted to include separate rooms for (a) the pasteurizing, cooling, and bottling operations; (b) the washing and bactericidal treatment of containers and equipment. Cans of raw milk shall not be unloaded directly into the pasteurizing room. Pasteurized milk or milk products shall not be permitted to come in contact with equipment with which unpasteurized milk or milk products have been in contact, unless such equipment has first been thoroughly cleaned and subjected to bactericidal treatment. Rooms in which milk, milk products, cleaned utensils or containers are handled or stored shall not open directly into any stable or living quarters.

(6) *Toilet facilities.* Every milk plant shall be provided with toilet facilities. Toilet rooms shall not open directly into any room in which milk, milk products, equipment, or containers are handled or stored. The doors of all toilet rooms shall be self-closing. Toilet rooms shall be kept in clean condition, in good repair, and well ventilated. In case privies or earth closets are permitted and used, they shall be separate from the building and shall be of a sanitary type constructed and operated in conformity with the requirements of item 10, grade A raw milk.

(7) *Water supply.* The water supply shall be easily accessible, adequate, and of a safe, sanitary quality.

(8) *Hand-washing facilities.* Convenient hand-washing facilities

shall be provided, including warm running water, soap and approved sanitary towels. The use of a common towel is prohibited.

(9) *Milk piping.* Only "sanitary milk piping" of a type which can be easily cleansed with a brush shall be used.

(10) *Construction and repair of equipment.* All containers and equipment with which milk or milk products come in contact shall be constructed in such manner as to be easily cleaned, and shall be kept in good repair.

(11) *Disposal of wastes.* All wastes shall be properly disposed of.

(12) *Cleaning and bactericidal treatment of containers and apparatus.* All milk and milk products containers and apparatus shall be thoroughly cleaned after each usage and subjected immediately before each usage to an approved bactericidal process. When empty and before being returned to a producer by a milk plant each container shall be effectively cleaned and subjected to bactericidal treatment.

(13) *Storage of containers.* After bactericidal treatment all bottles, cans, and other milk or milk products containers shall be stored in such manner as to be protected from contamination.

(14) *Handling of containers and apparatus.* Between bactericidal treatment and usage and during usage containers and apparatus shall not be handled or operated in such manner as to permit contamination of the milk.

(15) *Storage of caps and parchment paper.* Milk bottle caps and parchment paper for milk cans shall be purchased and stored only in sanitary tubes and cartons, respectively, and shall be kept therein in a clean dry place until used.

(16) *Pasteurization.* The terms "pasteurization", "pasteurized", and similar terms shall be taken to refer to the process of heating every particle of milk or milk products to a temperature of not less than 142°F. and holding at such temperature for not less than 30 minutes in approved pasteurization apparatus, provided that approval shall be limited to apparatus which requires a combined holder and indicating thermometer temperature tolerance of not more than 1½°F., as shown by official tests with suitable testing equipment, and provided that such apparatus shall be properly operated and that the indicating thermometers and the recording thermometer charts both indicate a temperature of not less than 143½°F., continuously throughout the holding period. The terms "pasteurization", "pasteurized", and similar terms shall also include the process of heating every particle of milk or milk products to 160°F., and holding at that temperature or above for not less than 15 seconds in apparatus of approved design and properly operated. Provided that nothing contained in this definition shall be construed as disbarring any other process which has been demonstrated as of at least equal efficiency and is approved by the State health authority.

The time and temperature record charts shall be dated and preserved for a period of 3 months for the information of the health officer.

(17) *Cooling.* All milk and cream received for pasteurization but not pasteurized within 2 hours after it is received at the plant shall

within 2 hours of receipt be cooled to a temperature of 50°F. or less and maintained thereat until pasteurized, except during separation; and all pasteurized milk and milk products shall be immediately cooled to an average temperature of 50°F. or less, and maintained thereat until delivery.

(18) *Bottling.* Bottling milk and milk products shall be done at the place of pasteurization in approved mechanical equipment.

(19) *Overflow milk.* Overflow milk or milk products shall not be sold for human consumption.

(20) *Capping.* Capping of milk and milk products shall be done by approved mechanical equipment. Hand capping is prohibited.

(21) *Personnel, health.* Every person connected with a pasteurization plant whose work brings him in contact with the production, handling, storage, or transportation of milk, milk products, containers, or equipment shall furnish such information, permit such physical examinations, and submit such laboratory specimens as the health officer may require for the purpose of determining freedom from infection.

The health officer, or a physician authorized by him, shall in each such instance take a careful history and if such history suggests that such person may be a carrier of or infected with organisms of typhoid or paratyphoid fever or of any other communicable disease likely to be transmitted through milk and milk products he shall secure appropriate specimens of bodily discharges and cause them to be examined in a laboratory approved by him or by the state health authorities for such examinations.

(22) *Personnel, cleanliness.* All persons coming in contact with milk, milk products, containers or equipment shall wear clean outer garments and shall keep their hands clean at all times while thus engaged.

(23) *Miscellaneous.* All vehicles used for the transportation of milk or milk products shall be so constructed and operated as to protect the milk or milk products from the sun and from contamination. Such vehicles shall be kept clean, and no substance capable of contaminating milk or milk products shall be transported with milk or milk products in such manner as to permit contamination. All vehicles used for the distribution of milk or milk products shall have the name of the distributor prominently displayed.

The immediate surroundings of the milk plant shall be kept in a neat, clean condition.

Grade B pasteurized milk. Grade B pasteurized milk is grade C raw milk which has been pasteurized, cooled, and bottled in a milk plant conforming with all of the requirements for grade A pasteurized milk, and the average bacterial plate count of which at no time after pasteurization and before delivery exceeds 50,000 per cubic centimeter.

Grade C pasteurized milk. Grade C pasteurized milk is pasteurized milk which does not meet the requirements of grade B pasteurized milk, and which shall be plainly labeled "cooking only."

* * * * * * * *

INSPECTION OF DAIRIES AND MILK PLANTS

The production of milk by civilian or military agencies is ordinarily a commercial activity and is, therefore, governed by economic factors. Consequently, inspection is necessary in the enforcement of laws, rules and regulations designed to protect the consumer from disease. Inspection procedures have the additional value that they serve to educate the dairy or milk plant operator concerning measures which will remove potential sources of contamination and improve the quality of the milk.

Inspection agencies. The Bureau of Animal Industry, United States Department of Agriculture, and the United States Public Health Service act in advisory capacities in the formulation and promulgation of methods and procedures for the operation and inspection of dairies and milk plants. Most of the states provide for dairy and milk plant supervision and inspection and this work is likewise a function of many county and municipal governments.

The nature of the dairy industry renders it impracticable, in most instances, for a state government to enforce laws or regulations which would absolutely control production of milk for sale to the public. However, laws which, though general in scope and which pertain mainly to the character of the milk as sold to the consumer, can be and are enforced by local governments, particularly municipal governments. Usually, however, these laws do not provide for a system of control and supervision which would prevent the introduction of pathogenic organisms into the milk at the dairy. As a rule, they rely mainly upon supervised pasteurization, and control of handling subsequent to pasteurization, to insure the delivery of a safe milk to the consumer.

It has been found, generally, that the production of a reasonably safe raw milk can be accomplished only under the supervision of a group or commission of private individuals. Such milk is known as certified milk.

Dairy inspection. Milk is procured for issue to troops either from a civilian owned dairy or from a dairy operated by the army. The civilian owned dairy may or may not be inspected by civilian agencies, and where such inspections are made they vary greatly in scope and thoroughness. Before approving any given dairy as a source of milk supply for

troops, the character of the inspections, if any, that are made and the degree of supervision exercised by civilian authorities should be determined. In the case that acceptable inspections are not made by civilian agencies, the dairy in question should be inspected by army inspectors prior to approval as a source of supply, and periodically thereafter.

Inspection of dairy animals. The inspection of dairy animals is primarily an inspection for the presence of disease and other abnormal physical conditions which would so affect the quality of the milk as to render it unsuitable for consumption. Particular attention should be devoted to the detection of the common diseases and physical conditions which affect the quality of the milk, such as tuberculosis, infectious abortion, diarrhea, any disease or condition associated with general symptoms, or with acute or chronic inflammatory conditions of the udder.

In making an inspection of a dairy herd for the purpose of detecting disease or physical conditions which would impair the quality of the milk, the inspector should search for the following general conditions:

1. Evidence of sickness, as indicated by such general symptoms as emaciation, loss or impairment of appetite, or disinclination for activity.
2. Inflammatory conditions of the udder or the secretion of bloody, stringy or otherwise abnormal milk.
3. The presence of any septic conditions such as suppurating wounds, septic metritis, etc.

The more important specific conditions which should be sought are:

a. Tuberculosis as evidenced by reaction to the tuberculin test (page 491).
b. Advanced pregnancy or recent parturition (from 15 days before to 5 days after calving).
c. Infectious abortion as shown by agglutination or complement fixation tests or by history of abortion (page 495).

Diseased or physically unfit dairy animals. The milk produced by a cow presenting evidence of any of the conditions mentioned above should be rejected. If such an animal is a member of a herd serving as a source of milk supply for troops, the entire supply should be rejected unless and until she is excluded from the herd, and no herd should be accepted or

continued as a source of supply until all affected animals have been removed therefrom. No animal removed from a herd for any of these conditions should be restored to the herd until a thorough examination shows that she is free from any physical condition or disease that would affect adversely the quality of the milk.

If milk is obtained from a herd maintained by the army, any animals that are producing, or that might produce milk which would endanger the health of the troops should be removed from the herd and handled, treated, or disposed of in accordance with recognized procedures and in the manner prescribed by existing regulations or orders. In the case of communicable diseases, the local civilian laws and regulations relative to quarantine should be observed.

Sanitary inspection of dairies. A sanitary inspection of a dairy is made for the purpose of determining the presence of sources of contamination and detecting conditions which would serve to convey contamination into the milk or promote the growth of bacteria contained in the milk. It includes an investigation of the environment in which the milk is produced, the equipment for and methods of handling the milk, and the health of the personnel who handle the milk.

As milk is an excellent culture medium for many of the pathogenic organisms, introduction of only a few organisms may result in the consumer receiving a heavily contaminated milk. The methods employed in handling milk at a dairy are necessarily such as to create many opportunties for the introduction of organisms, and the milk can be protected from contamination only by the strict observance of sanitary precautions. The sanitary inspection is therefore, an important and necessary safeguard.

Many factors are essential in the production of safe, clean milk, but these factors vary greatly in importance under different conditions and must be evaluated accordingly by the dairy inspector. Clean milk having a low bacterial count can be consistently produced only when all of the conditions listed below are present:

a. Well groomed, healthy cows.
b. Disinfected utensils.

c. Small top milking pails, or other means of preventing foreign material from entering the milk during milking.
d. Clean milkers, if milking is done by hand.
e. Clean milking machines, if milking machines are used.
f. Immediate and adequate cooling of the milk after milking.

Inspection of milk plants. In the inspection of a milk plant, the inspector is concerned primarily with the detection of errors in the technique of pasteurization which would result in failure to destroy all the pathogenic organisms or in re-contamination of the pasteurized product. The inspection involves a study of the procedures employed in receiving, pasteurizing, cooling, bottling, storing and delivering the milk including environmental conditions, the health of the employees, and the suitability and cleanliness of the apparatus and equipment.

In certain instances where pasteurized milk is obtained from milk plants, it is impracticable for army officials to inspect the herds from which the milk is bought by the operator of the plant. In such cases, the inspection of the milk supply at its source is restricted to inspection of the milk plant.

In dealing with the operators of civilian owned dairies or milk plants, the army inspector acts only as an advisor and has no authority to enforce corrective measures, except through cooperation with local health agencies. In the event that the owner fails to remove or correct factors that render the milk actually or potentially dangerous to health, the army inspector should recommend to proper military authority that the milk supply be rejected for use by the troops.

In the case of a dairy or milk plant operated by the army, the inspector should make suitable recommendations to the responsible agency for the correction of any defects revealed by inspection.

The score card method of inspection. In order that dairy and milk plant inspections may yield their full value in information, and furnish data by which the quality of the milk may be judged, they must be conducted in a systematic manner and in accordance with a pre-conceived plan. The diverse character of the factors to be considered and the varying degrees of importance of the different conditions, render

it necessary that the method of inspection be such as to insure the consideration of each factor concerned and provide a means of evaluating and expressing the effect which any departure from the normal will have on the quality of the milk.

In the score card system of inspection the factors or conditions to be inspected are listed or grouped to form a series of items. Each item is allotted a numerical rating consisting of a certain number of points for a perfect or ideal condition. The total value in points given to each item is so weighted that the total score for a farm or plant in which each item inspected was perfect, as compared with the standard adopted for inspection purposes, would be 100 points. The actual score to be given each item inspected is determined by deducting from the number of points allotted for perfection a penalty in points for all defects. The number of points remaining is the score. The total number of points scored constitutes a percentage rating for the farm or plant inspected.

Methods of scoring. Each item to be inspected is allotted a number of points which are to be included in the total score if the condition in question is without defects. Thus, in scoring the lighting of a stable, 4 square feet or more of properly distributed window glass area per cow is perfect and allotted a value of 2 points out of the 100 points allotted for the dairy farm. However, if on inspection, it is found that only 3 square feet of window area per animal are actually provided, then one point is deducted, and one point only is allowed for lighting.

In many instances, the number of points to be deducted for a given defect can be predetermined and will be the same in every case. If, however, the defective condition under consideration is one which varies from perfection in degree only, the deduction to be made must be determined by the inspector at the time of inspection. Thus, in the example given above, if 4 square feet of window glass area are actually provided per animal but the windows are poorly distributed, the deduction might vary from a fraction of a point to three points, depending on the degree to which the lighting of the stable was adversely affected by the position of the windows.

Score cards. Examples of score cards used in the inspection of dairy farms and milk plants are given in Appendices V and VI.

The score cards shown in Appendix V are those used by the Health Department of the District of Columbia, and are typical examples of score cards employed by civilian inspection agencies.

The score cards given in Appendix VI differ in some respects from those ordinarily used by state and municipal governments. Relatively greater value is given those conditions which are, or that might become, sources of contamination with pathogenic organisms. Also, each item is subdivided into a larger number of parts for which penalties may be given for defects in order to insure a more searching and thorough inspection, and the penalties for the various parts of an item are so valued that, in most instances, if serious defects are found a minus score may be given for the item.

The value of the score card method of inspection. The score card method of inspection provides the inspector with a list of the ordinary defects to be considered and indicates the average relative value of those sanitary conditions which potentially affect the quality of the milk. The score attained is not a measure of the existing purity of the milk, but rather a record of conditions under which the milk is produced or handled.

An acceptable score,—that is, a score of more than 60,—(*infra*) does not alone indicate that a given dairy or milk plant is a satisfactory source of supply, nor does a low score signify that the milk is necessarily dangerous to health at the time of inspection. A number of minor defects may cause a low score for a dairy or milk plant which, for the time being, is producing a safe milk. Another dairy or milk plant may have a high score and at the same time produce dangerous milk because of failure to correct some one condition.

The chief value of the score card method of inspection is educational, in that it records the corrections and changes required and shows their relative importance. It also affords a means of evaluating the improvement or deterioration in sanitary conditions between inspections.

In determining the suitability of a dairy or milk plant as a source of supply for troops, factors other than the score must also be considered. As shown in Section III of the score cards (Appendix VI), any condition which would render the milk dangerous to the health of the troops should be re-

garded as rendering the milk unsuitable for use by troops, regardless of the score attained on inspection.

Relation of the score to the bacterial and sediment content. The score and the bacterial and sediment content of the milk are indirectly related to the extent that the milk produced by a dairy with a high score will usually have a low bacterial count and a low dirt content. However, conditions which are not or cannot be scored may operate to produce a high bacterial and sediment content, or factors which lower the score may not increase the number of bacteria or the quantity of dirt in the milk. The bacterial count and sediment content of the milk should, therefore, be considered together with the score, but milk having a count of more than 200,000 bacteria per c.c. prior to pasteurization, or an excessive dirt content, should be rejected for use by troops.

The score as a basis for rejection. A low score usually indicates that the conditions under which the milk is produced are such that they constitute an actual or a potential menace to the health of the troops. Given a dairy which, at the time of inspection, is producing milk with a bacterial count of less than 200,000 per c.c. and a sediment content of less than 2.5 mgms. per pint, or a milk plant producing Grade "A" pasteurized milk containing less than 30,000 bacteria per c.c., the values of the score may be stated as follows, provided no condition is known to be present which renders the milk dangerous to health.

Score	Suitability as a source of supply
90 or more	Excellent
80 to 89	Very good
70 to 79	Good
60 to 69	Fair
Below 60	Poor

A score of less than 60 ordinarily represents conditions which militate against the continued production of a safe milk supply, and, therefore, indicates that the dairy or milk plant should not be utilized as a source of supply for troops.

Laboratory control. Laboratory tests afford the final means of determining the quality of the milk and whether or not the milk is suitable for issue to troops. The principal

tests employed for this purpose are the macroscopic colony count, the microscopic count of bacteria, the reductase test, the phosphatase test, the sediment test and the tests for fat and solids not fat content. Tests are occasionally made for the presence of added water, preservatives and coloring matter.

Laboratory equipment and personnel trained in laboratory work are required for the performance of all these tests, except the sediment test. The technique employed should, in each instance, be that given in the *Standard Methods of Milk Analysis*, American Public Health Association.

Sampling. Samples for bacteriological and chemical analysis are taken at various times during the process of producing and handling the milk. If taken from bulk milk, the sample must be representative of the entire contents of the container. If intended for bacteriological analysis, the sample must be taken under aseptic conditions and, in any event, contamination of the milk remaining in the container must be avoided.

Samples for bacteriological analysis. The sample bottle should be glass stoppered and have a capacity of from two to four ounces. The collecting tube is a glass or aluminum tube or pipette, from 20 to 22 inches long and holding about 22 c.c. Paddles may be required for stirring the milk. They are usually made of metal and are about one and one-half inches wide. All apparatus which will come in contact with the milk, including bottles, pipettes, collecting tubes, or paddles, should be wrapped, individually, in a good grade of paper and sterilized by dry heat.

As it is difficult to mix thoroughly the contents of a large can of milk by shaking or stirring, bulk milk is usually sampled with a collecting tube. The collecting tube, with the top of the tube open, is slowly passed from the surface of the milk to the bottom of the can or other container so as to obtain a representative section of the milk. The top of the tube is then closed with the finger and the sample transferred to a sample bottle. Generally, from 10 to 20 c.c. are sufficient for bacteriological analysis, but if a greater quantity is desired, the operation may be repeated.

The sample may be taken by lowering the sample bottle into the milk with a piece of fine copper wire from 20 to 30 inches long which has been fastened to and wrapped around the neck of the bottle before sterilization. If this method is used, the milk should be thoroughly stirred with a sterile metal paddle before the sample is taken.

Samples of bulk milk for bacteriological analysis should be taken at the dairy farm and from the cans as they are received at the milk plant for pasteurization. The results of these analyses indicate the efficiency of the methods used to prevent contamination.

Samples of bottled milk are obtained by selecting a bottle at random from among a number at the milk plant, in the delivery wagon or truck, or as delivered. It is at times desirable to obtain one sample at the milk plant immediately after pasteurization and another when the same lot of milk is delivered, in order to determine the effect which the methods of storage and transportation may have on the growth of bacteria in the milk.

Samples for chemical analysis. At least a quart is required for chemical analysis and the sample is usually taken from the bottled milk. If obtained from bulk milk, the milk must be thoroughly mixed before the sample is taken.

Transfer of samples to laboratory. The samples for bacteriological analysis should be transferred to the laboratory as soon as possible. When taken they should, if practicable, be packed in ice, and kept at a temperature of 45°F. until examined.

The phosphatase test of pasteurized milk. During recent years a number of studies have been made with a view to devising a laboratory test which would determine if a given sample of milk had been subjected to sufficient heat for a long enough period of time to effect pasteurizaton. The most satisfactory of the tests proposed are based on the presence of the enzymes amylase and phosphatase in milk and the fact that these enzymes are inactivated when milk is heated to 143°F. for thirty minutes. The phosphatase test, as reported by Kay and Graham, and as modified by other workers, has yielded the most reliable results. Briefly, the test is made by adding a reagent containing phenylphosphate to the milk, which is then incubated. If phosphatase is present the phenylphosphoric ester is hydrolyzed, freeing phenol which is detected quantitatively by testing with Folin and Ciocalteu reagent. If phenol is present, the solution is blue in color, and the intensity of the blue color is determined by comparing the color of the sample with known color standards, or by means of a tintometer. A deep blue color indicates that the milk has not been heated, a blue or light blue color that the milk is underpasteurized,

and only a faint blue color, or a trace of blue, that the milk has been heated to 143°F. for at least 30 minutes.

The phosphatase test is sufficiently delicate to show a decrease of five minutes in the pasteurizing time, or the addition of 0.1 per cent of raw milk to the pasteurized milk.

FIG. No. 137. Parts of apparatus for the milk sediment test.

Sediment test. The standard sediment test is a method of determining the amount of insoluble, visible dirt in one pint of milk. One pint of thoroughly mixed milk is passed through a cotton disk one inch in diameter contained in an apparatus devised for that purpose (Figures No. 137 and 138). The disk is removed from the tester, sprayed with a disinfectant, such as mercuric chloride solution, and dried at room temperature or in a hot air oven.

The amount of dirt retained on the disk is determined by comparing the dried disk with a series of four or eight standard disks which represent 1.25, 2.50, 3.75 and 5.00 milligrams of dirt, respectively, or 0.25, 0.50, 0.75, 1.00, 1.25, 2.50, 3.75 and 5.00 milligrams of dirt, respectively (Fig. No. 139).

The amount of insoluble dirt in milk is indicative of the cleanliness of the environment in which the milk was produced and handled. While the same factors that produce a relatively

large dirt content will usually be the cause of a high bacterial count and a low inspection score, a considerable quantity of dirt may be present in milk having a low bacterial count and a high score. In such cases, a sediment test will indicate the existence of potential sources of contamination.

As the sediment test of raw milk is indicative of the cleanliness of the conditions under which the milk is produced and

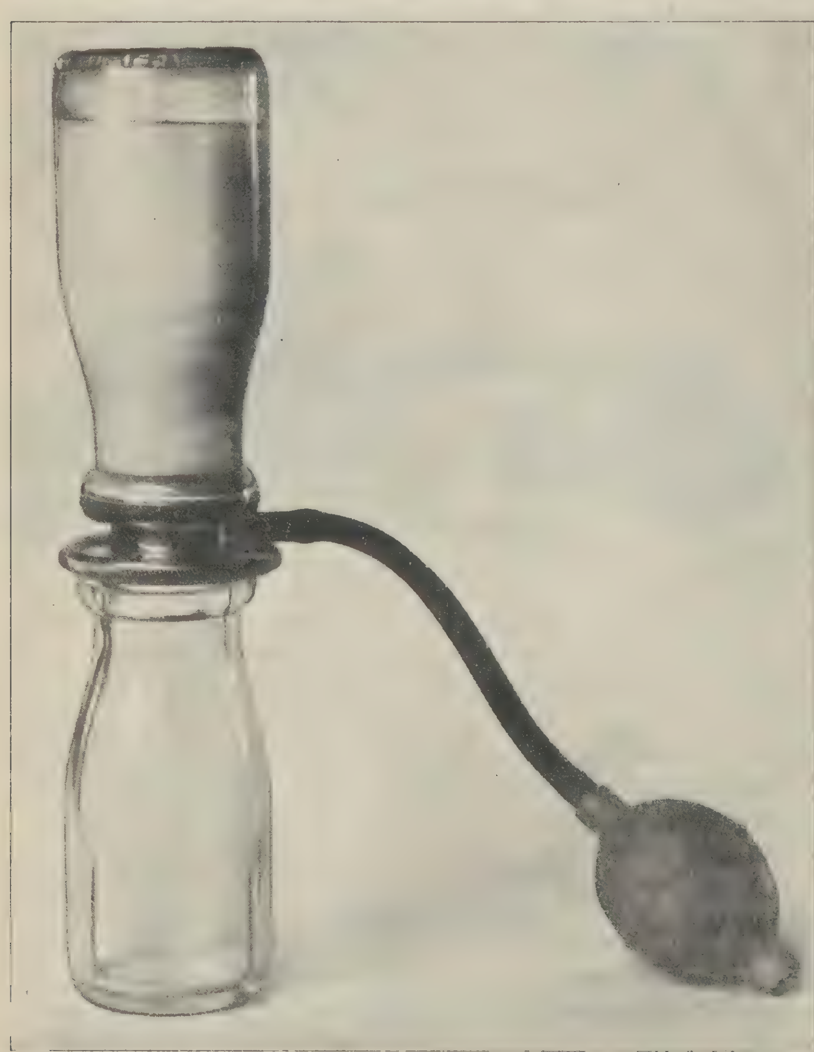


FIG. No. 138. Assembled apparatus for the milk sediment test. The milk flows through the pad between the bottles, which catches and retains dirt.

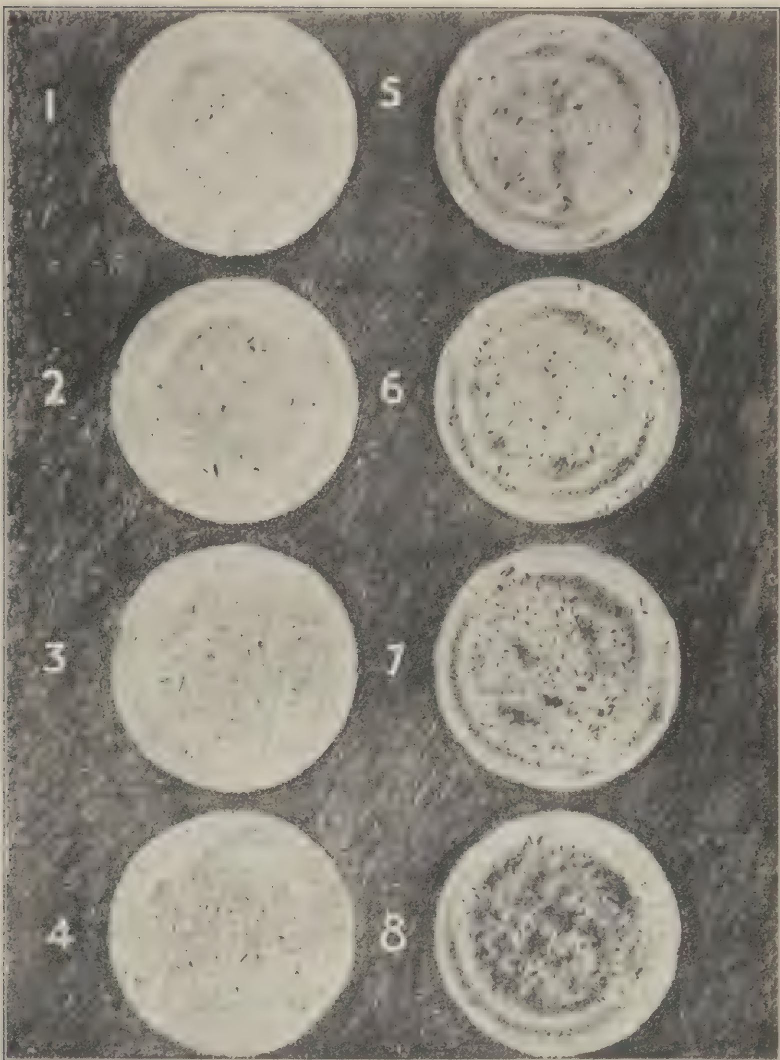


FIG. No. 139. Standard disks showing the amount of sediment in milligrams obtained from one pint of milk.

Disk No. 1 ......0.25 mgms.	Disk No 5 ......1.25 mgms.
Disk No. 2 ......0.50 mgms.	Disk No. 6 ......2.50 mgms.
Disk No. 3 ......0.75 mgms.	Disk No. 7 ......3.75 mgms.
Disk No. 4 ......1.00 mgms.	Disk No. 8 ......5.00 mgms.

(Mickle, F. L. Conn. Standard Test for Dirt in Milk, Conn. Health Bull. Feb. 1928. pp. 27.) (Standard Methods of Milk Analysis, American Public Health Association).

handled at the dairy, the sample to be tested must be taken prior to straining, clarification, or filtration. The sediment test of pasteurized milk will show only the dirt remaining after clarification and is therefore of little value as a method of determining the cleanliness of the procedures employed in producing and handling the milk.

Any measurable quantity of dirt in raw milk justifies an assumption that the milk has been in contact with potential sources of contamination with disease-producing organisms. The methods used in the production and handling of such milk should be subjected to thorough inspection to determine the defects which permit dirt to enter the milk.

Milk is classified on the basis of the sediment test according to the amount of dirt retained on the disk as follows:—

Clean—Less than 1.25 milligrams per pint.

Fairly clean—More than 1.25 and less than 2.5 milligrams per pint.

Slightly dirty—More than 2.5 and less than 3.75 milligrams per pint.

Dirty—More than 3.75 and less than 5 milligrams per pint.

Very dirty—5.0 milligrams or more per pint.

Pasteurized milk which is not classified as clean should be rejected for use by troops, regardless of the bacterial count or inspection score. The reason for the continued presence of *any dirt* in a pasteurized milk supply, even though the milk is classed as clean, should be determined by thorough inspection of the milk plant and if the responsible defects are not subsequently corrected, the milk should be rejected for issue to troops.

QUALITY OF MILK TO BE ISSUED TO THE TROOPS

The milk issued to the troops should be Grade "A" pasteurized milk (page 537). It should contain less than 2.5 milligrams of dirt per pint before pasteurization and less than 1.25 milligrams after pasteurization. Further, it should have been produced by animals known to be free from disease, and under proper sanitary conditions as determined by inspection. It should be cooled immediately after pasteurization to a temperature of less than 50°F. and kept at that temperature until time of delivery. It should contain not less than 8 per cent of solids not fat, and 3.25 per cent of milk fat.

All milk for use by the troops, either as a beverage or in cooking, should be delivered in milk bottles, filled immediately subsequent to pasteurization. Milk which is delivered in cans should be issued to troops only when bottled milk cannot be obtained and when suitable precautions can be and are taken to prevent recontamination at the milk plant, during transportation and in messes of the using organizations. Where Grade "A" pasteurized milk is not procurable, condensed or evaporated milk should be used.

MILK PRODUCTS

The milk products commonly used by the troops include cream, condensed milk, butter and oleomargarine, cheese, ice cream, and dried milk. The conditions under which these products are produced should be subjected to the same supervision and control as those surrounding the production of fresh milk, and, in most communities, such supervision and control is exercised by civilian authorities. However, it is not ordinarily practicable for military agencies to supervise or even determine by inspection the sanitary conditions under which milk products are produced, except when they are produced by government owned facilities. In most instances, inspection consists only of that made of the finished product prior to purchase, on receipt, or at the time of issue to troops.

Condensed milk. Condensed milk is primarily fresh milk from which a part of the water has been removed and to which sugar may or may not have been added. It is usually prepared as evaporated milk, sweetened condensed milk, or condensed skim milk.

Evaporated milk contains not less than 25.5 per cent of milk solids and not less than 7.8 per cent of milk fat.

Sweetened condensed milk is milk to which sugar (sucrose) has been added and which contains not less than 28 per cent of milk solids and 8 per cent of milk fat.

Condensed skim milk contains not less than 20 per cent of milk solids.

The condensed milks may be canned or sold in bulk. The canned product is, as a rule, issued to troops.

Inspection of condensed milk. Condensed milk which is to be issued to the troops should have been produced under the

supervision of an acceptable inspection agency. Such supervision should include the dairy farms where the milk is produced, and the procedures employed for handling, manufacturing, transporting and storing of the fresh milk which is to be condensed, and of the finished product.

Deterioration of condensed milk is evidenced by the formation of gas, the development of abnormal tastes or odors, or by discoloration. Gas formation is due to improper sterilization, defective cans, and the growth of yeasts or moulds. Discoloration may be due to fungi or to the caramelization of the sugar. Tastes or odors are usually due to rancidity, staleness, the action of the acid on the metal of the container or of the apparatus used in the manufacture of the milk, or to the growth of bacteria or fungi.

Certain of the constituents of the milk may settle out to form precipitates in the milk or on the bottom of the can. The casein may be precipitated to form lumps or curds. A deposit of sediment may be formed on the bottom of the container due to the settling out of the sucrose or mineral matter. These conditions are due to defective methods of manufacture, long storage or storage under improper conditions, or may occur when old milk is transported. A precipitate does not, however, necessarily indicate that the milk is unsuitable for food.

Result of inspection. Any stocks of condensed milk showing evidence of deterioration, as manifested by the presence of gas, abnormal odors or tastes, or discoloration, should be rejected for food purposes. If on inspection defective cans, or cans in which precipitates have formed, are found prior to purchase, the entire lot or code should be rejected. If the milk is in the possession of the government, the contents of defective cans, or milk containing precipitates due to physical changes, if otherwise acceptable, may be passed as suitable for food. Such supplies should, however, be very carefully examined for evidence of other conditions which would render the milk unfit for food.

Butter. Butter is the butter fat derived from milk or sweet or sour cream, formed into a mass together with water and small amounts of other natural constituents of milk, such as curd, lactose and acid. It may or may not contain added salt. Butter should contain not less than 80 per cent of milk fat and not more than 16 per cent of moisture.

Usually, edible butter is classified as dairy, creamery, ladled or renovated. Dairy butter is butter that is made on a farm by the usual domestic procedures. Creamery butter is made in a creamery. If the cream is separated at the dairy farm, it is transported directly from the farm or cream station to the creamery. Ladled butter is butter made by re-working miscellaneous lots of butter which are still wholesome. Renovated butter is made by melting, clarifying and otherwise refining or re-working butter fat in order to improve the flavor or eliminate impurities.

As a rule, only creamery butter or, under suitable conditions, dairy butter, is issued to the troops.

Sanitary control of butter production. The butter making process *per se* does not destroy pathogenic organisms which may be contained in the raw cream. As tubercle bacilli, typhoid bacilli and other organisms will survive in butter for considerable periods of time and be transmitted in a virulent form to the consumer, it is essential that the production of butter be safeguarded in the same manner as the production of milk. This can be accomplished only by the exercise of adequate sanitary control over all phases of the production of milk, cream and butter.

All cream from which butter is to be made should be pasteurized. The holding method of pasteurization is preferable for this purpose, although the flash method is satisfactory if properly controlled (page 509). Pasteurization serves not only to destroy the pathogenic organisms and reduce the number of saprophytic organisms, but also to eliminate certain undesirable gases and volatile substances.

The dairy farms producing milk from which butter is to be made and the creameries in which it is manufactured should be operated under the supervision of official inspection agencies. Ordinarily, the butter is purchased as the finished product without inspections being made by army inspectors during or prior to manufacture. In view of this, only those supplies should be purchased which have been produced under the supervision of acceptable civilian inspection agencies.

Storage of butter. Butter may be packed in wooden tubs, boxes or tin cans of various sizes. Usually, however, it is prepared as one, two or five-pound rolls or one-half or one-pound prints.

If butter is to be held for any considerable length of time, it should be placed in cold storage at a temperature of from 5 to 10 degrees below zero F. At this temperature, high grade butter may be held without deterioration for as long as six months, provided the storage place is kept dry and clean. Butter should not be held at chill room temperatures of from 20°F. to 30°F. for longer than about one month. Deterioration is manifested by the loss of flavor and the development of disagreeable tastes and odors.

Butter exhibits a marked tendency to absorb odors and tastes from other substances and should not, for this reason, be stored in the same place or close to odorous substances, such as fish, cheese, or certain vegetables.

Methods of inspection. The inspection of a dairy farm at which butter or cream for butter making is produced, is conducted in the same general manner as in the case of a farm producing fresh milk only. If butter is made at the farm, the apparatus and utensils used for that purpose are included in the inspection.

The method of inspecting a creamery differs in no essential respect from procedures employed in the inspection of a milk plant, except that consideration must also be given to the sanitary condition of the apparatus used for butter making and the methods of handling the product.

Inspection of the finished product. In the inspection of the finished product, consideration is given to the condition of the package or container in which the butter is packed, to soundness or any indications of deterioration, and to the flavor, body, color, and salt content. The results of inspection are expressed as a score based on a maximum of 100 points. The standard method of scoring salted creamery butter awards a maximum value in points for different factors as follows:

Factors	*Maximum number of points*
Flavor	45
Body	25
Color	15
Salt	10
Package	5
Total	100

Butter packed in tubs, cans, boxes or other large containers is usually sampled by means of a trier thrust to the bottom of the mass. The samples thus obtained may be inspected for flavor, body or color, or utilized for such laboratory examinations as may be required.

Flavor. Flavor includes taste and odor and is the most important of the scoring factors. It is seldom that a perfect score is given for flavor. The flavor of an average, high grade product will usually have a score value of from 37 to 42 points.

The flavor should be fresh, clean and sweet. If the aroma and taste are especially pleasant, the score for fresh butter may be as high as 42 or 43 points. Storage butter may be given a score of from 38 to 40 points if the flavor is particularly good. Fresh or storage butter which has an average fresh, clean and sweet flavor is usually given a score of from 37 to 39 points.

Undesirable flavors may be designated as foreign, off, rancid, strong, metallic, garlicky, yeasty, cowy, and by various other descriptive terms. Slight taints may reduce the flavor score to 36 points or less. Somewhat more noticeable defects in flavor usually result in a score of from 33 to 35 points, while butter having a pronounced disagreeable flavor may be scored as low as 27 points. Edible butter is seldom given a flavor score of less than 27 points.

Body. The body of the butter should be firm and compact with a good granular structure and texture. It should present a broken irregular structure when pulled apart. Such butter may be given the maximum score of 25 points for body. Score cuts of from less than one to more than five points are made for softness, lack of uniformity or poor structure or texture. The body of such butter may have a salve-like texture and show a smooth surface when broken apart.

Color. Butter should be a light to medium straw color without mottled areas, streaks or specks. Such a color may be awarded the maximum score of 15 points. Score cuts of from one-half to five or more points should be made for uneven coloring, specks, spots, streaks or mottled areas, or for dull or dark coloring.

Salt. If salt is present in proper amount, evenly distributed through the butter and causing no grittiness, the maximum score of 10 points may be awarded. Cuts are given for any departures from these standards.

Package. If the package is sound, clean and free from mould or other defects, it may be given a score of five points. Deductions are made for broken, dirty, mouldy or otherwise damaged containers.

Results of inspection. Butter which does not have a score of 90 or more should be rejected for issue to the troops. However, the quality of the finished product is indicated by the score only when it has been produced under sanitary conditions. Consequently, any butter which has not been produced under the supervision of, and passed by, an official inspection agency, civilian or military, should be considered as unsuitable for food, regardless of the score.

Cheese. There are many kinds of cheese which differ widely in their physical and chemical characteristics and in flavor. The American cheddar cheese and the Swiss cheese are most commonly issued to troops.

Many of the different kinds of cheese may contain those pathogenic organisms which are transmissible by milk. The dairies producing milk from which cheese is to be made should be subject to the same supervision by official inspection agencies as those producing fresh milk. The milk should be pasteurized and precautions taken to prevent recontamination during the manufacture and subsequent handling of the cheese.

Owing to its physical qualities and more stable character, cheese is not nearly so important a disease-transmitting agency as fluid milk or butter.

Inspection of cheese. Ordinarily, the inspection of cheese by military agencies is limited to inspection of the finished product prior to purchase, in storage, at time of issue, or in the messes of the using organizations. Dairy inspections and the inspections of cheese factories are usually performed under the supervision of civilian health agencies.

Cheese is usually inspected for body and texture, flavor, appearance, color, odor, acidity, salt content, excess moisture and adulteration or foreign matter.

Cheese should be rejected for purchase or issue when it shows any evidence of contamination with undesirable bacteria or infestation with parasites. Other indications of unsoundness for which the cheese should be rejected are abnormal flavors, mould which is not characteristic of the type of cheese being in-

spected, abnormal color, or damage due to handling or poor packing.

Vitamin D milk. The vitamins are discussed on page 418. Milk naturally contains very little, if any, vitamin D. The generally accepted methods of producing vitamin D milk are by the irradiation of the milk, by the addition of vitamin D concentrates to the milk, and by feeding cows irradiated yeast.

A tentative minimum standard of potency for vitamin D milk has been accepted by the Council on Foods, American Medical Association. This standard provides that irradiated milk shall contain 135 units of vitamin D per quart, and that milk fortified by the addition of vitamin D concentrates shall contain 400 units per quart. The unit is the U.S.P. XI vitamin D unit (page 423).

Irradiation of milk. The usual method of irradiating milk consists of exposing a flowing film of milk, about 0.4 mm. thick, to ultraviolet rays for about sixteen seconds. The ultraviolet rays are produced by carbon arc or quartz-mercury lamps. When properly employed this method does not alter the taste of the milk, and milk so treated has a vitamin D content of at least 135 units per quart.

The operator of a milk plant producing irradiated milk must obtain a license from the Wisconsin Alumni Research Foundation, Madison, Wisconsin. The application for a license must have the approval of the local County Medical Society, and the plant must meet certain requirements, among which is one that the milk must be pasteurized. No license fee is charged, but certain small royalties are collected.

Addition of vitamin D concentrates. Commercially produced vitamin D concentrates may be added to the milk in quantities sufficient to give at least 400 units per quart. The most commonly used brands are Vitex, Clo-Dee and Sun-A-Sured. Vitex is a trade name for a cod liver oil extract containing concentrated vitamin D. Clo-Dee is also a vitamin D concentrate extracted from cod liver oil by a special process. Sun-A-Sured is a vitamin D concentrate obtained by activating ergosterol. Vitamin D concentrates may be added to fresh pasteurized milk, evaporated milk or dried milk.

Feeding irradiated yeast to cows. Vitamin D milk containing more than 400 units per quart can be produced by feeding

irradiated yeast to the cows. This milk is also known as "metabolized milk" and has the advantage that it contains the required amount of vitamin D when produced. The yeast must be purchased from the firm controlling the patents, and a license must be obtained from the Wisconsin Alumni Research Foundation, Madison, Wisconsin.

The yeast is usually fed to the cows two or more times daily. Each cow receives from four to seven ounces of the yeast daily, the amount varying according to the quantity of milk produced by the individual animal.

Control. The production of vitamin D milk is controlled with regard to vitamin content by bio-assay (page 423) as prescribed by local laws and regulations, or under the terms of license. The frequency of such tests varies greatly, but usually at least four bio-assays per year are required.

CHAPTER XII.

MESS SANITATION

An army mess includes all the facilities employed in preparing food for and serving it to troops. From an administrative point of view, there are four principal types of army messes. These are the company mess, the general mess, the post mess and the hospital mess. A *company mess* serves only one basic unit, which may be a company or a detachment. A *general mess* is one which serves two or more organizations. A *hospital mess* serves the patients of a hospital. A *post mess* may be established for the purpose of serving officers, enlisted men who are rationed separately from their organizations, or civilian employees. It is supported financially by its members and not by government funds or rations. It is, however, a government agency, in that the commanding officer of the station or camp in which a post mess is maintained is responsible for its operation. The mess officer is appointed by the commanding officer, except that in the case of a post mess which is strictly an officers' mess the mess officer may be elected by the members of the mess.

Normally, army messes, with the exception of post messes, are operated for the benefit of enlisted personnel only. The supplies for the mess are furnished by the government and the commanding officer of the organization concerned is directly responsible for the conduct of the mess. The funds for any officers' mess, whether it is conducted by the members of the mess, by an officers' club, or as a post mess, are furnished by the members of the mess. The commanding officer of a camp or station is, in general, responsible for the conduct of any officers' mess located within his jurisdiction. In hospitals, the mess for mem-

bers of the Army Nurse Corps is usually operated separately from the messes for officers, enlisted patients, or enlisted hospital personnel.

Administrative control. An army mess is administered by or under the direct supervision of the commanding officer of the unit it serves, and he is responsible to higher authority for all matters pertaining to the operation of the mess.

The mess officer. The commanding officer of a unit may appoint a subordinate officer as mess officer. The mess officer functions under the direct supervision of the commanding officer, to whom he is responsible for the management of the mess.

Enlisted and civilian mess personnel. The personnel of a mess normally consists of the mess sergeant and a sufficient number of enlisted men to operate the mess. Civilians may be employed in a mess, especially in a post mess. The mess sergeant is in direct charge of the mess personnel. He is responsible to the mess officer, if there is one, or to the commanding officer if there is no mess officer, for the duties performed by the mess personnel, enlisted or civilian, in accordance with instructions and orders issued by either the mess officer or the commanding officer.

Usually, only a part of the enlisted personnel of a mess are assigned to permanent duty in the mess, while the remainder are detailed for temporary duty only and are replaced by others at relatively short intervals. As a rule, the mess sergeant, cooks, assistant cooks, butchers and certain key men in the organization of the mess, such as the mess hall orderlies, are placed on permanent duty in the mess. The kitchen police, that is, the men who perform such unskilled labor as general cleaning, dishwashing, or the preparation of vegetables, are usually assigned for temporary duty and are replaced at intervals of from 24 hours to a week.

Sanitary control. The Medical Department is responsible for the sanitary inspection of messes and for reports and recommendations relative to sanitary defects. In scope, the sanitary control of a mess includes the following factors:

Sanitation of mess buildings.
Inspection of food when received at kitchens.
Storage of food to prevent deterioration.
Cleanliness of cooking, serving and eating utensils, and other mess equipment.

Disposal of kitchen wastes.

Methods of formulating menus and character of the food served.

Methods of serving food.

Physical examination of food handlers.

Training of mess personnel in mess sanitation.

Sanitary features of mess buildings. Mess buildings, which include the kitchens and mess halls or dining rooms, should be provided with screened windows and doors during the house fly season, and the screens should be kept in good repair (Chapter XVIII). Ample provision should be made for natural ventilation and mess buildings should, where practicable, be equipped with exhaust ducts and roof ventilators (page 132). Natural lighting should be obtained by means of windows and skylights. The artificial lighting utilized in mess halls and the kitchens should be semi-indirect. If direct lighting is used, care should be taken to avoid undue glare (page 145).

The floors of kitchens and mess halls should be made of impervious material, preferably concrete, and drainage outlets should be provided. The walls should likewise be constructed of material that can be cleaned by scrubbing with soap and water.

Care of kitchen and mess hall floors. Dirty kitchen or mess hall floors, or wooden floors soaked with liquids containing organic matter, tend to attract flies. Concrete floors should be flushed with water from a hose once or twice daily. Grease spots and stains which remain after flushing should be removed by scrubbing with soap and water or with lye. Wooden floors that cannot be flushed should be scrubbed or mopped daily with hot water and soap.

Inspection of food supplies received at a mess. All food received at a mess should be inspected by the mess sergeant, the mess officer, or the commanding officer of the organization to which the mess belongs. The primary purpose of this inspection is to determine if the food in question is of proper quality and free from contamination. If evidence of deterioration, spoilage, or contamination is found, the proper Medical Department officer, either the surgeon or the veterinarian, should be notified and the suspected articles reserved for his official inspection. The methods of conducting the inspection

of food received at the mess are the same as those heretofore discussed in connection with the inspection of the various classes of food supplies (page 432).

Contaminated or deteriorated food may be disposed of as waste or returned to the quartermaster or the agency from which it was purchased, depending on the conditions under which it was issued to or purchased by the mess.

Storage facilities. Surplus and reserve food supplies should be protected from insects, such as flies and roaches, and from dust and dirt. Perishable foods should be stored at a temperature which will inhibit the growth of organisms. In a permanent mess, the storage facilities usually consist of refrigerators, or cooling or cold storage rooms, vegetable bins, bread cabinets, containers, such as bins or the regulation galvanized iron can, for sugar, flour, rice, oatmeal and similar articles, and a room or rooms for the storage of canned goods.

Refrigerators. The purpose of the refrigerator or ice box is to prevent the spoilage of food for a short time until it can be prepared for consumption. Ordinary refrigerator temperatures, which vary from about 45° to 55°F., will not prevent the growth and multiplication of organisms and thus preserve food for an indefinite length of time. A temperature of 50°F. will, however, inhibit and retard bacterial growth to a degree which will prevent spoilage for a short period of time.

The mechanical type of refrigerator, which utilizes a gas as a refrigerant, is preferable, but satisfactory results can be obtained with a properly constructed and operated ice refrigerator.

The capacity of a mess refrigerator, or the number of refrigerators required for a mess, depends on the number of persons served by the mess. Sufficient refrigerator space should, however, be provided to permit the storage of perishable supplies and allow for air spacing between the various pieces or articles of food, and between the stored food and the sides and top of the compartments.

If a refrigerator is opened at frequent intervals it is difficult to maintain a temperature low enough to delay spoilage to any considerable extent. In order to minimize this difficulty and keep the major portion of the supplies at as low a temperature as possible, the reserve food should be stored in a large refrigerator and the supplies for current use in a smaller refrigerator. The storage compartments of the larger refrigerator containing

the reserve supplies should be opened only at such intervals, usually once or twice a day, as are necessary to store the reserve supplies and to transfer the articles needed for current use to the smaller refrigerator.

The interior of a refrigerator should be kept scrupulously clean and free from odors. The interior of the food compartments should be scrubbed daily with soap and water. The walls, top and bottom of the compartments should be kept as dry as practicable, the water of condensation being wiped off at such intervals as may be necessary. Food should be stored in the refrigerator in such a manner that each of the various articles is surrounded by an air space. Each piece of meat should be hung on a hook so that it does not touch the walls or bottom of the compartment, or any other object. If allowed to do so, slime will form on the meat where it is in contact with another surface and promote spoilage (page 460). Any article of food which shows the slightest evidence of spoilage should be removed from the refrigerator at once.

Foods such as fish, cheese or bananas, produce odors which may be absorbed by and cause tastes in other foods, and should not be stored in the same compartment with such foods as milk or butter.

A refrigerator should not be utilized to store foods, such as cabbage, tubers, or pickled foods, which can be preserved by ordinary storage.

Vegetable bins (Fig. No. 140). Open bins should be used to store surplus supplies of such vegetables as potatoes, onions, carrots or beets. The sides of the bin should be made of spaced slats so that air will enter and circulate through the bin. The larger bins should be so constructed that the bottom has sufficient slope to permit the older vegetables to be removed for use without disturbing more recently added supplies.

Bread cabinet. In a permanent mess, the bread should be stored in a screened bread cabinet. Such a container will exclude insects and permit sufficient aeration of the contents to inhibit the development of molds.

Dishwashing. The terms "dishes" and "eating utensils" include all tableware, such as cups, saucers, plates, glasses, knives, forks and spoons, and dishes and utensils used in preparing and serving the food. Dishes may be contaminated with the causative agents of diseases, especially the respira-

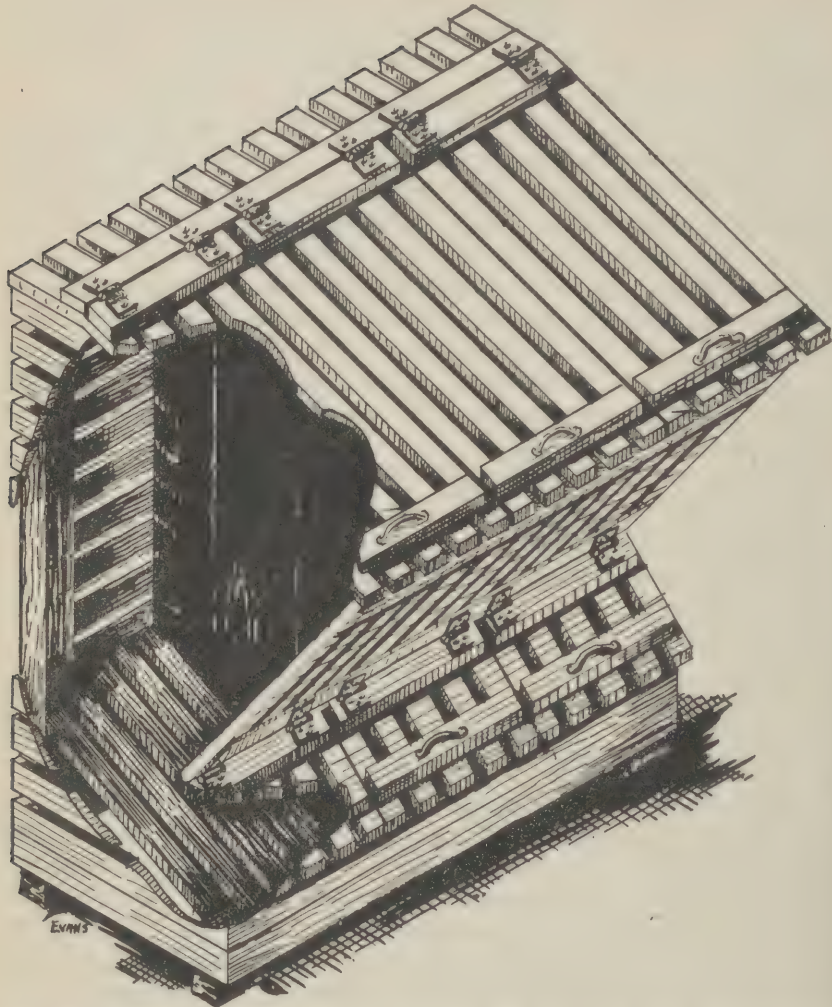


FIG. No. 140. One type of small vegetable bin showing open construction and sloping bottom.

tory diseases and intestinal diseases, and they may be a very important factor in the transmission of these infections from person to person.

In dishwashing, the dishes are brought into contact with each other through the medium of the dish water, or by the use of dish cloths, or in handling by dishwashers. Thus a few contaminated dishes may serve as a source from which patho-

genic organisms are transferred to a large number of dishes during the process of washing.

In permanent messes, the dishes are washed by hand or in dishwashing machines. The proper washing of dishes involves the removal of all visible material from the dish or utensil and the destruction of all pathogenic organisms on the dish and in the dish water. The cleansing of a dish requires the use of soap or other detergent, but cleansing alone will not disinfect the dish. A dish may be clean and still carry large numbers of pathogenic organisms. The disinfection of dishes and the dish water is accomplished by heat, or by the application of chlorine.

The water in which a number of dishes are washed may be a most important agent for the transmission of pathogenic organisms. As the dishes are washed, many organisms are removed from the dishes into the water, and unless these organisms are destroyed as they are introduced into the water they rapidly increase in number and the water becomes heavily contaminated. When this occurs, the dishes frequently carry more organisms after washing than they did when placed in the dish water. Thus, dishes which were free from pathogenic organisms before being washed may be contaminated during the washing process and serve to transfer infection to those who use them at the next meal.

In order for the dishes, and the water in which they are washed, to remain free from pathogenic organisms, the organisms must be destroyed either by heat or by a disinfectant. Under practical working conditions dishes cannot be sterilized by heat in the sense that all organisms are destroyed. Actually, the dishes are pasteurized by the application of the principles of pasteurization as described on page 508. Immersion of the dishes in water at a temperature of 160°F. for one minute will destroy the pathogenic organisms. If the temperature is lower the washing time must be longer, until at a temperature of 140 to 145°F. the dishes must remain in the water for at least thirty minutes (page 508). If temperatures higher than 160°F. are used, the washing period may be shortened, but a washing period of less than one minute is not usually practicable.

Because of the difficulties encountered in disinfecting dishes by the use of heat, considerable attention is now being

given to the use of chlorine for this purpose. The dishes having been cleaned by washing, and rinsed in hot water to remove the soap or detergent are immersed for not less than two minutes in a chlorine solution containing at least 50 parts per million of free chlorine. The chlorine solution when freshly prepared should contain 200 parts per million of available chlorine. This solution can be made by dissolving Grade A calcium hypochlorite in proportion of one ounce of the calcium hypochlorite to 25 gallons of water (page 292). The available chlorine content should not be allowed to fall below 50 parts per million at any time during the disinfecting process.

Hand dishwashing. In messes where dishwashing machines are not available, the dishes must be washed by hand in kitchen sinks or other large containers. Disinfection of dishes by hand washing can be accomplished only by continuous and strict supervision. In practice, it is seldom that those washing the dishes will use water that is hot enough, or hot water for a long enough period of time, to destroy the pathogenic organisms on the dishes or in the dish water. Consequently, where dishes are washed by hand, they should be disinfected with chlorine (*supra*).

Dishwashing machines. There are many different types of dishwashing machines. In all machines the dishes are passed through a compartment in which the dishes are cleaned by being washed with jets or a spray of hot water containing a suitable detergent. The dishes are then rinsed with hot, clear water, either in the same compartment in which they were washed or in a second compartment. In some instances the washed dishes are rinsed with a chlorine solution (*supra*), and the dishes may or may not be rinsed with clear water to remove the detergent before being rinsed in the chlorine solution. If the dishes are to be used immediately, the chlorine should be removed by rinsing with unchlorinated water. If the dishes are not to be used until the next meal, a second rinsing to remove the chlorine is unnecessary.

The temperature of the wash water should be maintained at not less than 160°F., and the dishes should remain in the washing water for at least one minute. Frequently, because of factors inherent in the manual operation of the ordinary dishwashing machine, such as too rapid passage of dishes through the washing stage, lack of skill on the part of the operator, or failure to heat the water sufficiently, the temperature of the wash water is

too low, or the washing period is too short to disinfect the dishes or the dish water. Under these conditions, washing serves only to remove the gross material, leaving the finer particles and viable organisms on the surface of the dishes, and disinfection must be accomplished by the rinse water. Where hot water is used for rinsing, the temperature of the rinse water should be at least 180°F. at the beginning of the rinsing period and should not fall below 170°F. at any time during the rinsing period. If hot rinse water is not available chlorinated rinse water should be used (*supra*). The dishes should remain in the hot rinse water for at least one minute, or in the chlorinated rinse water for at least two minutes.

At times, especially in the operation of a large mess, speed is an essential feature of the dishwashing process. If the dishes are washed for one minute in wash water the temperature of which is maintained at not less than 160°F. throughout the washing period, the rinsing period may be reduced to ten seconds, provided the temperature of the rinse water does not fall below 180°F. In dishwashing machines of the conveyor type, the washing period may be reduced to 40 seconds if the temperature of the wash water is held at 165°F. or higher and washing is followed by rinsing for 20 seconds with water at a temperature of not less than 180°F.

In order to insure that the wash water and the rinse water are maintained at the proper temperature and that the washing and rinsing time is sufficient for disinfection to occur, dishwashing machines should be equipped with automatic temperature and time control devices. One machine of this type has been developed by Lieut. Col. W. C. Cox, M. C., and is being used at a few military stations. This machine can be operated only when the wash water, or the rinse water, reaches a predetermined temperature, and the dishes remain automatically locked in the washing compartment for the desired length of time, which is usually for one minute at 160°F. The dishes are then rinsed for ten seconds at a temperature of 180°F.

Drying of dishes. All dishes should be dried in the air regardless of whether they are washed by hand or with a machine or disinfected by heat or with chlorine. Dish towels should never be used to dry dishes.

Care of dishes and utensils. Dust and insect proof cabinets or cupboards should be used to store dishes and utensils

when not in use or, if these are not available, the dishes and utensils should be protected by covering with cloths.

Boilers that have been used for any purpose except boiling water should be cleaned by scrubbing with hot soapy water, followed by scouring with scouring soap, after which they should be rinsed in hot clear water and dried. Coffee boilers should be scoured with scouring soap daily. Bake pans should be scrubbed with hot soapy water, rinsed with hot clear water, and dried. They should never be scoured as scouring will remove the bronze or bluing. Bake pans may be greased with clean lard or bacon grease to prevent rusting.

Mess tables. Mess tables may have solid tops or they may be made with the removable inner boards. If the boards are fastened in place, they should have sufficient space between them to permit easy cleaning. The top of a solid top table should be made of some one of the glazed composition products, as it is difficult to remove organic matter from between the boards of a solid wooden top. Mess tables are of various shapes and sizes but, usually, the long table is used. Stools, benches or chairs may be provided. The benches may be attached to the tables.

Care of mess tables. Mess tables should be scrubbed after each meal with hot soapy water, or with hot water and scouring soap. If the tables have removable inner boards, these boards should be taken out and the edges cleaned. If the boards of a table top are not removable, all organic matter in the cracks or spaces between the boards should be removed by means of a knife blade or similar instrument each time the table top is scrubbed. Mess stools, chairs or benches should be wiped with a clean, damp cloth after each meal and scrubbed with hot water and soap once each week.

Formulation of menus. A menu should provide for the proper quantities of each food constituent and for articles which will be acceptable to the group served by the mess in question. In formulating menus, care must be taken to vary the kinds of food served and methods of preparing and serving the articles of food. Few foods can be prepared and served in the same manner day after day without soon becoming non-acceptable to the greater proportion of the group served. The frequency with which a dish can be repeated without becoming non-acceptable varies greatly with the different articles of

food and is, to some extent, modified by the characteristics of the individuals making up the group served. For example, meat and potatoes can be, and are, served day after day and, with variation in methods of preparing, do not become non-acceptable to the average American soldier. On the other hand, troops tire quickly of the same kind of sweet pastry or of such vegetables as carrots, cabbage or beets.

The menu period. A menu should be formulated for each day for a period of days, usually for a period of five or ten days. The menu period should be planned for an odd number of days, such as five or ten, and not for weekly periods, so that the same menu will not be served on corresponding days of each week.

The most satisfactory menu for the average army mess is a 10-day menu providing for basic dishes to which other dishes may be added as opportunity is offered to secure desirable articles of food. The acceptability of the food served by a mess can be enhanced, and the nutritional value of the ration increased, by the addition or substitution of special dishes at irregular intervals. This can be accomplished by the mess officer or mess sergeant through the exercise of a certain amount of ingenuity and foresight without materially increasing the cost of the ration.

Contamination of food during preparation and serving. Given food supplies which are suitable when received at the mess, certain precautions must be taken to prevent contamination during the process of preparation and serving. The most important sources of contamination are intestinal and respiratory discharges transferred to the food by food handlers. Contact with contaminated utensils, insects or dust may also serve to infect the food. The methods of protecting the food from contamination by insects, dirty utensils, dust and dirt, are discussed above. Improper handling or storage may facilitate the growth of pathogenic organisms or the production of toxins in prepared food prior to consumption.

Food handlers. While all permanent food handlers are, or should be, physically examined for communicable diseases before going on duty in a mess, it does not follow that permanent food handlers who have been so examined will not contaminate the food. A most dangerous food handler is one who develops intestinal or respiratory disease while on duty in the mess, even though it is only a slight coryza or a mild diarrhea, and remains on such duty long enough to infect the food served in the mess.

The health of all mess personnel should be continually observed by the mess officer or mess sergeant. Obviously, any member of the mess personnel who develops an acute illness would be relieved because of physical inability to perform duty. However, virulent pathogenic organisms may be transferred to the food by food handlers who are themselves suffering only from mild, transient, or early symptoms of infection.

Undoubtedly, many of the cases of common diarrhea and common respiratory disease occurring among troops are due to infection transmitted by food which has been infected by food handlers having the disease in a mild form. In order to control the transmission of infection in this manner, *any* food handler who exhibits *any* mild, non-incapacitating symptoms of respiratory or intestinal disease, including occasional sneezing or coughing, a nasal discharge, or unusually frequent visits to the toilet or latrine, should be immediately relieved from duty in the mess by the mess officer or mess sergeant and reported to the surgeon of the command for examination. If the surgeon finds that such a food handler presents symptoms of a mild respiratory or intestinal infection, but is physically able to perform duty, he should be given duty not involving the handling of food and should not be returned to duty in the mess until all symptoms have disappeared. This procedure increases the operating difficulties and may at times impair the efficiency of the mess. It is, however, ultimately far more economical for the organization concerned than it would be to permit food handlers having an infectious disease to remain on duty in the mess and spread infection among the troops of the command.

All food handlers should be trained to observe a high standard of personal cleanliness and should be constantly supervised in this respect by the mess officer or mess sergeant in order that a high standard will be maintained. The hands should be kept scrupulously clean at all times, except for the food material that may adhere to them during work. It is especially important that the hands be thoroughly disinfected after visiting the toilet or latrine. The men should be trained to keep their hands away from the mouth and nose and to disinfect their hands immediately should they become contaminated with oral or nasal secretions.

A solution for disinfecting the hands of food handlers should be kept available in the toilets used by food handlers and in the kitchen of the mess. A one or two per cent solution of cresol is

satisfactory for this purpose. All food handlers should be trained and required to wash their hands in this solution after visiting the toilets, or whenever their hands might have become contaminated with discharges from the respiratory tract or with excreta. After washing, the hands should be dried in the air, and not with towels or cloths. The solution may be placed in a basin or pan, or a drip container may be used.

All food handlers should be required to bathe and shave daily, to keep their finger nails clean and cut short, and their hair properly trimmed. They should also be required to wear clean outer garments, preferably white in color, while on duty. While the observance of these precautions does not directly prevent the transmission of disease-producing organisms, they contribute markedly to a spirit of cleanliness on the part of the food handlers, and thus tend to promote a psychological reaction which will lead them to devote more attention to cleanliness in every respect. On the other hand, in messes where the food handlers are not required to wear clean clothing and where rules relative to bathing, shaving and care of the finger nails are not strictly enforced, the food handlers will also frequently fail to wash their hands when going on duty or after visiting the toilet and will take fewer precautions to avoid contaminating the foods they handle.

Contamination of prepared food. Many cooked foods are good culture media for pathogenic organisms. This is especially true of boiled or roasted veal, fresh pork, or chicken, although many other foods may also serve as excellent media for the growth of organisms. If such foods become contaminated with pathogenic organisms subsequent to cooking, and are retained for a number of hours prior to serving, the organisms will increase sufficiently in numbers or produce sufficient toxin to cause illness when consumed. When food of this nature has been prepared for one meal but has not been consumed, it should not, as a rule, be served at a subsequent meal without thorough recooking. Such recooking is necessary in order to destroy any organisms, or the toxins of organisms, with which it may have been inoculated subsequent to the first cooking.

Certain dishes, because of the method of preparation and the materials from which they are made, are particularly prone to transmit the organisms or toxins causing food infection. The dishes most commonly implicated are salads

and hash. Salads prepared from veal or chicken are frequently incriminated as transmitting agencies in outbreaks of food infection. Usually, the salad has been made from left-over meat and a filler consisting of raw or but partially cooked vegetables. The left-over meat ingredient may be contaminated or the raw vegetable component may carry the organisms into the salad. Salads are served cold and are frequently prepared a number of hours prior to serving, or even the day before, and, under these conditions, contaminating organisms may multiply and produce toxic products in sufficient quantities to cause illness. Storage at average refrigerator temperature in the interim between preparation and serving will not prevent the growth of certain of the organisms that cause food infections.

Hash is usually made from left-over beef or pork, with potatoes, onions and beef stock. This mixture makes an excellent culture medium and there is always danger that the left-over components have been contaminated during prior handling. Frequently, in making hash, the finished product is not well recooked because the ingredients have been previously cooked. It is sometimes made and then allowed to stand for hours, possibly over night, and merely re-warmed before serving. Such methods permit pre-existing organisms to continue growing and do not destroy preformed toxins. As in the case of salads (*supra*), storage of hash at ice box temperature will not prevent the growth of certain pathogenic organisms.

In order to prevent the transmission of disease-producing organisms and toxins by left-over food, the serving of dishes made from left-over foods in which such organisms will grow should be reduced to a minimum. Every effort should be made to avoid preparing excess quantities of food, so that left-over food need not be re-served to prevent undue wastage. The meat ingredients of a salad should not be mixed with the vegetables until shortly before the salad is to be served. If left-over meat is used, it should be thoroughly recooked before being put into a salad. The same procedure should be followed in making hash, except that if left-over meat is used, the hash should be thoroughly cooked after being mixed and just prior to serving.

Cold meat cuts may be served without recooking if ordinary precautions are taken to prevent contamination. Pickled vege-

tables or acid foods, such as cooked fruits may, as a rule, be served cold without danger of transmitting infection.

Leafy vegetables. Leafy vegetables which are served raw, or after only partial cooking, may carry pathogenic organisms to the consumer. The transmission of pathogenic organisms by leafy vegetables is largely mechanical, as the vegetable itself is not an efficient culture medium for the organisms. Contamination is usually derived from the soil in which the vegetables are grown, but they may be contaminated by handlers or by contact with infected objects subsequent to harvesting.

Leafy vegetables which are known to have been, or which might have been grown in soil fertilized with human excreta, should be rejected for purchase or issue as food for troops. In any event, any leafy vegetable which is to be eaten raw should be prepared by thorough washing in running water and, if feasible, by scalding in hot water. It is particularly important in the tropics, or in other localities where human excreta (night soil) is used as fertilizer for truck gardens, that in purchasing leafy vegetables, great care be exercised to obtain those grown in uncontaminated soil and that proper precautions be taken in the preparation for consumption of any vegetables which have been purchased in local markets.

Milk. As many of the pathogenic organisms grow freely in milk, only Grade A, pasteurized milk or canned milk should be served to troops (page 552). Where milk is served as a beverage or for use in cereals, the individual bottle should be used.

Methods of serving food. Three basic factors are to be considered in serving food in a mess, regardless of the method adopted. First, the food must be served in such a manner that it will not be contaminated during the process of serving. Second, the method of serving should enhance, or at least not lessen, the acceptability of the food or its appeal to the group appetite. Third, the food should be so served as to reduce wastage to a minimum.

There are two general methods of serving food in a mess; the line service, or cafeteria, method, and the table service method. Each of these methods has its advantages and disadvantages from the standpoint of its effect on the acceptability of the food and on wastage.

FIG. No. 141. Line service in a general mess.

The line service or cafeteria method. When food is served by the line service method, the individual being served passes by serving tables or containers and receives a portion of such of the articles of food on the menu as he may desire. Second helpings may be served if desired. The food may be served from ordinary containers or, in a well equipped permanent mess, steam tables may be employed as serving tables. All the food may be served by line service, or certain articles may be placed on the mess tables. For example, the bread and beverage may be placed on the mess tables and the remainder of the menu served by line service.

In order for line service to be most effective, the food must be so displayed on the serving tables that it appeals to those to whom it is to be served. Hot foods must be served hot and the portions must be of proper size. The food should be served rapidly and there should be as little delay as practicable in serving additional portions.

Table service method. With the table service method, the food is placed on the mess tables before or at the time the troops enter the mess hall. Table service may be combined with line service as discussed above.

FIG. No. 142. Mess tables arranged for table service in a general mess.

Comparative efficiency of line service and table service. If properly operated and carefully supervised, the line service method is the best method of serving food in the average mess where any considerable number of troops are to be fed. There is less danger of contaminating the food served or that left over, because it is handled by fewer individuals and can be better protected on the serving table than on the mess table. The line service method permits wastage to be held at a minimum without depriving those served of all the food they desire. Also, less personnel is required to serve food by line service than by the table service method.

However, unless the line service method is properly conducted it tends to decrease the acceptability of the food. Where the food is poorly served, the more or less solid articles, such as meat and potatoes, are frequently covered or mixed with liquid or semi-liquid articles, rendering the meal, as a whole, less acceptable and promoting waste. Further, more time is required after the troops are admitted to the mess hall to serve a given number by the line service method than by the table service. If a large number of troops are served where there is insufficient shelter for long lines, the line method may necessitate the ex-

FIG. No. 143. Line service in the field.

posure of the troops to inclement weather while waiting to be served.

Given sufficient personnel and suitable equipment, well conducted table service will generally have a more favorable effect on the morale and contentment of the troops, and will usually be more efficient than line service. However, unless ample mess personnel and good equipment are available, the line service method should be used.

FIELD MESSES

A field mess is a mess for feeding troops in temporary camps, in bivouac, on the march, or in combat. As a rule, the field mess is a company mess.

Usually, the garrison ration is issued to troops in temporary camps, and where conditions permit, articles such as fresh vegetables are purchased locally. Either the field or garrison ration may be issued to troops on the march or in bivouac. Here also the ration may be supplemented by fresh vegetables or fruits purchased from local sources. Only the field ration is normally issued to troops in combat (page 412).

Generally, the same sanitary factors must be considered and the same measures adopted to prevent the transmission of disease by the food served in a field mess as in the case of a permanent mess. A field mess differs from a permanent mess largely in the character of the equipment used, which in the case of the field mess must necessarily consist of that which can be transported by the command or improvised in the field.

Equipment. The essential equipment of a field mess consists of a rolling kitchen or field range, and the utensils required for cooking and serving the food. Normally, the kitchen is housed under canvas—a fly, or a wall tent and fly being used for this purpose. A field mess may be housed in a building, if a building is available for that purpose. Where necessary and feasible, improvised devices, such as underground cooling boxes, suspended food containers, and appliances for the disposal of wastes are installed.

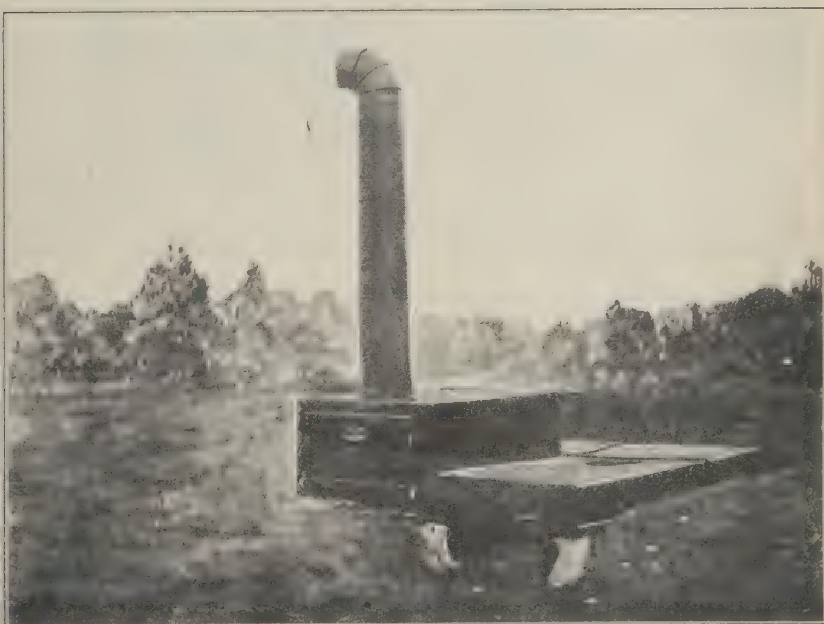


FIG. No. 144. Army field range No. 1 with alamo attachment.

Field cooking equipment. Companies in the field may be equipped with either the army field range or a rolling kitchen. Two types of field ranges are provided. Army field range No. 1 (Fig. No. 144) with the alamo attachments, has a cooking capacity sufficient to supply one hundred and fifty men in the field. Army field range No. 2 is smaller and is designed to cook for fifty-five men.

FIG. No. 145. Company kitchen of a field mess. Army field range No. 1 in operation.

The rolling kitchen is essentialy a cooking range mounted on a two or four wheeled trailer (Fig. No. 146). The typical rolling kitchen when properly operated, will cook sufficient food for a war strength infantry company. It is provided with kettles in which food may be cooked while the kitchen is moving.

The army field range has the advantage that it can be transported in a truck, while the rolling kitchen must be trailed and is difficult to move over poor roads or broken terrain. The field range can be installed on the wooden floor of a building or railway car, if it is equipped with an improvised clay, sand or other fireproof base. The rolling kitchen is cumbersome, as compared with a field range, and is difficult to use in these situations. On the other hand, the rolling kitchen provides a greater variety of

FIG. No. 146. One type of rolling kitchen.

cooking facilities than a field range. It has the great advantage that food can be cooked or kept warm on the march and a hot meal can thus be provided for the troops at a halt or when camp is reached.

Storage devices for field messes. In warm weather, in a camp of more than one or two days' duration, a field mess should be equipped with devices for the temporary storage of perishable food. If ice is available, an underground ice box may be utilized. If ice cannot be procured, the food may be stored below the surface of the ground, where the temperature is less than the atmospheric temperature, or it may be placed in suspended screened containers and cooled by air circulation. If streams, springs or ponds are available, perishable food may be stored at a lowered temperature by placing it in waterproof containers and immersing the containers in the water.

Underground ice box or cooling box. Under ordinary conditions, an underground ice or cooling box will be found useful for the storage of meat, milk, vegetables or other perishable foods. A typical device consists of a double walled box sunk into a pit in the ground so that the upper or outer lid is level with the surface of the ground (Fig. No. 147). The box is constructed so that a space three to six inches wide separates the inner and

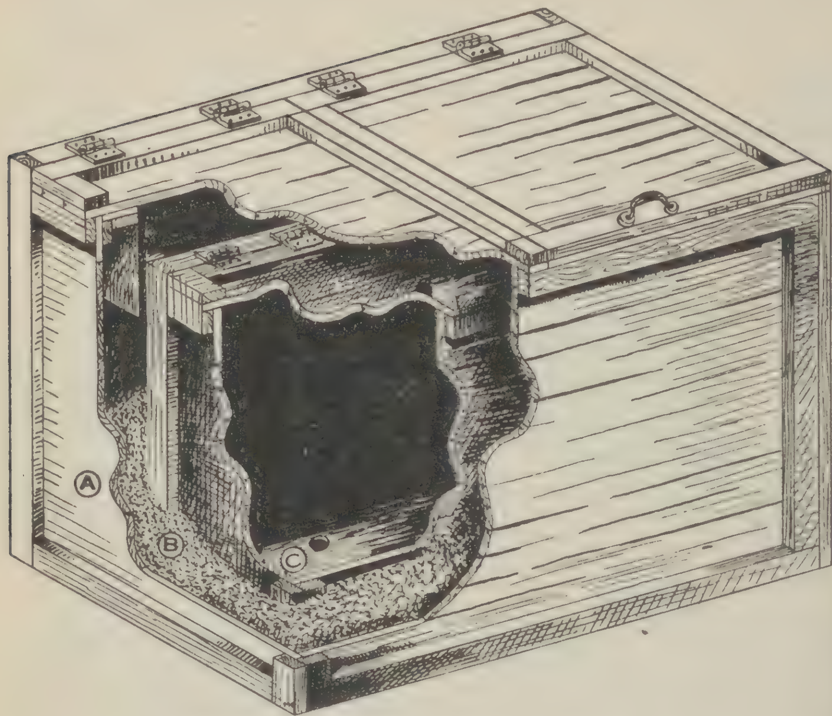


FIG. No. 147. Underground ice or cooling box. A—Outer wall. B—Insulating material. C—Inner wall.

outer walls and the two bottoms. This space is packed with material which is a non-conductor of heat, such as sawdust, grass, hay, straw, or burlap. Two lids are provided—one for the inner and one for the outer box—and separated by a space of from 2 to 4 inches. Earth is packed into all crevices between the outer wall of the box and the sides of the pit. A drainage ditch should be dug around the box to carry away storm water. The box should have a drain pipe, or at least a drain outlet, leading through the bottom of the box into the earth below, through which any fluids that accumulate in the box, or water used in cleaning the box, may be drained away. Unless the soil is porous and will readily absorb the drainage water, a small gravel or rock soakage pit should be installed underneath the box (page 729).

The double walled box may be made by placing one packing box within a larger one. If material is not available for the

construction of a double walled box, a single box or box-like wooden container may be used, or a pit lined with puddled clay or stones may be installed.

The underground ice or cooling box may be of any convenient size. A box four feet long, three feet wide, and three feet deep, inside measurements, has sufficient capacity for the average company mess.

If ice is used, and it should be used when available, an ice compartment is constructed in one end of the box with a drain pipe passing through the bottom of the box, so that water from the melting ice will not come in contact with the food.

The underground box may be used as a cooling box without ice. While not as effective as an ice box, the cooling box is, nevertheless, a valuable aid in the preservation of food in the field. In dry weather the effectiveness of the box, whether used as an ice box or a cooling box, can be increased by dampening the packing material between the walls or wetting down the earth around the box.

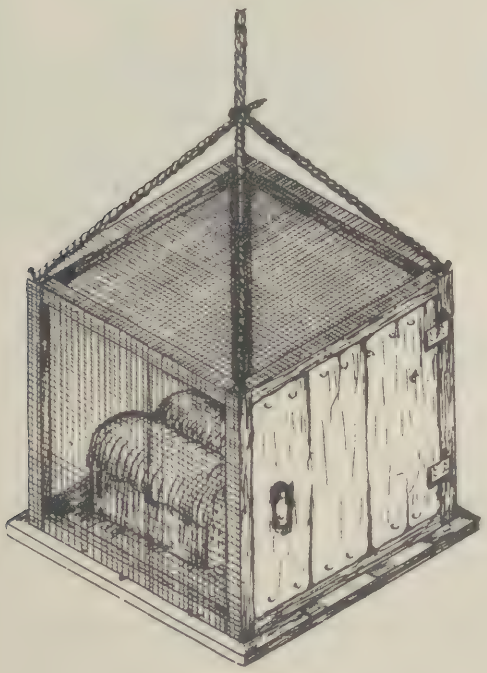


FIG. No. 148. Suspended food container.

Suspended food containers. A suspended food container usually consists of a screened box so constructed that free circulation of air is obtained, but access to the food by flies or other insects is prevented. It is suspended by ropes or cords from a tree branch, tripod or cross pole. A typical screened suspended food container may be made as shown in Fig. No. 148. Wrapping the container in wet burlap will increase its cooling value.

The suspended food container is useful for the temporary storage of fresh meat, milk in bottles, or vegetables. It should not be used where the air contains any considerable amount of dust.

FIG. No. 149. Washing mess kits.

Mess kit washing. In the operation of a field mess the food is served by the line service method and individual mess kits are used. Each man cleans and cares for his own mess kit.

Mess kits should be washed in such a manner as to destroy all pathogenic organisms and prevent their transmission from one kit to another. This is accomplished by washing the kits in two changes of hot soapy water and rinsing in clear hot water followed by drying in the air.

The water containers for washing mess kits in temporary camps must, necessarily, be transportable, and the method of heating the water must be simple and not require elaborate

construction. In temporary camps, the facilities for washing mess kits usually consist of a set of three galvanized iron garbage cans placed over a fire trench. Two of the cans contain hot soapy water and the third hot clear water. All remnants of food are scraped from the mess kit into a garbage can or other container. The entire mess kit is then thoroughly washed in the hot soapy water in one of the containers and again in the hot soapy water in the second container. The kit is then rinsed in the hot clear water in the third container to remove the soap, and dried by shaking in the air.

FIG. No. 150. Washing mess kits, using two galvanized iron cans. One can contains hot soapy water and the other hot clear water.

The water in all of the containers should be kept steaming hot, boiling if practicable, while the mess kits are being washed. As long as the water is steaming, it is bactericidal for the pathogenic organisms usually found on mess kits. The water may, therefore, be used to wash a large number of mess kits without danger of transmitting these organisms, but from an esthetic point of view, the water in each container should be changed after it has been used to wash not more than 100 mess kits.

Where an open fire trench is used to heat the water for washing the mess kits, the heat of the fire and the smoke cause much discomfort. Flames and smoke can be minimized to some extent by starting the fire some time before the mess kits are to be washed so that at the time of washing the fire trench will contain a thick bed of coals.

FIG. No. 151. Device for washing mess kits in the field. (Courtesy of the Medical Field Service School, Carlisle Barracks, Pa.).

In camps of more than a few days duration, a more effective method of heating the water than that described above should be adopted. The principal feature of any permanent installation is an enclosed fire trench, fire pit or furnace equipped with a stack to facilitate adequate heating of the water and to carry the heat and smoke away from the men while they are washing their mess kits. Such a device is subject to many modifications depending on the local conditions and the ingenuity of those in charge. One such apparatus, as developed at the Medical Field Service School, is depicted in Fig. No. 151. The fire trench is constructed over a soakage pit (page 729) and has a stack at one end. The pit is eleven feet long, four feet deep and two feet wide, and filled to within one foot of the surface of the ground with stones,

broken rock, brick, or other material. A wall of stone, concrete or brick extending two feet above the top of the ground is built along each side to form a fire box, and to support the water containers. The stack is installed as shown in Fig. No. 151. The stack should have a damper. The water containers are made from 50-gallon oil drums by cutting the drums along the longitudinal axis about four inches to one side of the center (Fig. No. 151). Only drums with bungs should be used for this purpose and a drum should be cut and installed so that the bung is in the most dependent part. Pieces of iron pipe of sufficient length to extend from the bottom of the container to above the water level are threaded at one end to fit the bung holes and drilled at the other end to receive an iron rod to aid in screwing the pipes in and out. After the water containers are placed on the fire box, all openings between the sides of the containers and the walls of the fire box, between the ends of the containers, and between the rear container and the stack should be filled with clay or cement in order to prevent the escape of heat and smoke. This apparatus provides a good draft and requires only a relatively small amount of fuel. The men are protected from the smoke and the heat while washing their mess kits. The water containers are emptied by removing the pipes and allowing the water to drain into the soakage pit below.

Other types of permanent installations for washing mess kits consist of brick or stone fire boxes of various kinds equipped with a grate of iron bars or pipes and a stack. The water containers, which are supported by the walls of the fire box, are usually made of sheet iron and are drained by means of stopcocks and piping. The three containers may be connected with each other so that all may be drained as a unit. The water containers are of different shapes and sizes. The broad shallow container has the advantage that the water can be quickly heated. The fire box and the water containers should be wide enough to permit both sides to be used at the same time (Fig. No. 152).

Any permanent installation for washing mess kits should be placed under a roof to protect the troops during inclement weather.

FIG. No. 152. Device for washing mess kits in a permanent camp. (Courtesy of Colonel William B. Borden, M. C.).

PHYSICAL EXAMINATION OF FOOD HANDLERS

A permanent food handler is one whose routine duties require him to handle food to be consumed by others. Permanent food handlers may be on duty in a mess, a post exchange, commissary, officers' or service clubs, or any other agency where food supplies are handled. A temporary food handler, as distinguished from a permanent food handler, is one who is assigned to duties involving handling the food of others for short periods of time, usually from 24 hours to not more than a week. Rotating kitchen police are classed as temporary food handlers.

A temporary food handler may, of course, contaminate food in the same manner as a permanent food handler. The distinction between a temporary and a permanent food handler is purely arbitrary, and is made because of the administrative difficulties encountered in physically examining all men who serve as food handlers for short periods of time. Where

practicable, temporary food handlers should be physically examined prior to assignment to such duty. If they are not physically examined, their duties should be restricted as much as practicable to work not involving the handling of prepared food or that which is to be served raw. Furthermore, they should be carefully observed by the mess officer or mess sergeant for any signs of illness.

Every man who is to be assigned to duty as a permanent food handler should be reported by his organization commander, or the mess officer, to the surgeon of the command for a physical examination. If the man is found to be free from communicable disease and is not a carrier of any communicable disease, the surgeon should issue a certificate to this effect to the organization commander or mess officer concerned. No man should be assigned to duty as a permanent food handler who has not been examined by a medical officer and certified to be free from communicable disease and not a carrier. Permanent food handlers should be re-examined at intervals of not more than six months.

Permanent food handlers' certificates should be kept posted, or on file available for inspection in the place where the food handlers concerned are employed.

No man should be considered fit for assignment to duty as a food handler who, when physically examined, presents evidence of acute or chronic inflammatory conditions of the respiratory tract, or any signs or symptoms of venereal disease, intestinal disease or other communicable diseases.

The medical history of the examinee is of paramount importance in determining his fitness for duty as a food handler. Any history indicating that he may have had typhoid fever or bacillary or amebic dysentery should be regarded as rendering him unsuited for duty as a food handler. Careful inquiry should be made to determine if he is unusually susceptible to respiratory or intestinal infections, especially common colds and attacks of diarrhea. If so, he should not be assigned to duty as a food handler. In mobilization camps or other situations where the personnel consists largely of recruits, no man who is non-immune to measles or mumps should be placed on duty as a food handler.

When deemed desirable by the examining surgeon, the feces and urine may be examined bacteriologically to deter-

mine if the examinee is a carrier of the causative organisms of an intestinal disease. Where laboratory examinations are made, the feces should also be examined for *Endameba histolytica,* and no carrier of this organism should be assigned to duty as a food handler. Ordinarily, however, physical fitness for duty as a food handler is determined by the medical history of the examinee and the result of the physical examination. If either the physical examination or the history indicates that the examinee may be a carrier of disease, positive laboratory findings are confirmatory, but negative findings do not necessarily justify his assignment to duty as a food handler despite suspicious physical signs or history.

SANITARY INSPECTION OF MESSES

The principal purpose of a sanitary inspection of a mess is to determine the existence and nature of any defects which would result in contamination of the food and the transmission of disease-producing organisms to the troops, or which would impair the nutritive value or lessen the acceptability of the food as served to the troops. Any inspection includes the formulation and submission to proper authority of suitable recommendations for the correction of any defects found.

In scope, the ordinary sanitary inspection of a mess includes consideration of all factors concerned in the operation of the mess from the receipt of the food supplies to the serving of the prepared food. At times, limited inspections or special studies are required to determine the reasons for and the best means of correcting existing defects, as, for example, an investigation of the storage facilities or of the methods of serving the food.

Method of conducting an inspection. The sanitary inspection of a mess should be conducted in a systematic manner and in accordance with a preconceived plan in order that no factor will be overlooked. The method of inspection actually adopted in a given instance will, however, vary according to the nature of the mess and the purpose of the inspection. The more important features of mess inspection are considered in the following paragraphs.

Surroundings. The ground around the mess should be inspected for fly breeding material, drainage and general cleanliness.

Waste disposal. Garbage stands should be inspected for structural defects, cleanliness and evidence of spilled garbage. The condition of the garbage cans with regard to cleanliness, odors and defects in the cans or lids, and the care exercised to prevent the garbage from attracting flies should also be considered.

If the garbage is burned in incinerators located adjacent to the kitchen, the condition of the incinerator and the efficiency of its operation should also be investigated. Soakage pits for the disposal of liquid wastes from the kitchen should be inspected in a like manner.

Mess buildings. If the mess is housed in a building, the general condition of the building should be considered with reference to structural defects which would detract from its usefulness as a mess building. During the house fly season, special attention should be given to the condition of window screens and screen doors and to the enforcement of orders or instructions pertaining to their maintenance and use. Search should also be made for unscreened incidental openings which would admit house flies. The condition of the floors and walls with regard to cleanliness and the effectiveness of the methods used in cleaning them should be noted. The adequacy and condition of lavatory and toilet or latrine facilities should also be determined.

Kitchen utensils and cooking equipment. The cleanliness of the kitchen utensils and equipment serves as an excellent index of the efficiency of the mess, and the kitchen equipment which is presumed to have been cleaned should always be inspected for evidence of improper cleaning and inadequate care. While poorly cleaned pans or other equipment may not be directly concerned in the transmission of disease, they are evidence that the mess personnel is either inadequately trained or improperly supervised. The same spirit which will permit the use of dirty equipment will also countenance the existence of defects or conditions which will result in the transmission of disease to the troops. On the other hand, well cleaned equipment indicates that an effort is being made to conduct the mess in a proper manner.

Eating and serving utensils. The effectiveness of the methods used to cleanse and disinfect dishes, knives, forks and spoons or mess kits, should be investigated. In permanent messes equipped with dishwashing machines, the efficiency with which these machines are operated should be noted. The methods used to

protect this equipment from contamination between meals should likewise be considered. In temporary messes, where the individual mess kit is washed by its user, the suitability of the facilities provided for this purpose, the degree of supervision exercised over the washing of the mess kits and, in general, the efficiency of the procedure with regard to disinfection, should be determined by the inspector.

Storage facilities. The storage facilities and the methods of storing should be investigated with particular reference to protection from flies and other insects, dust, dampness, rats and mice, and deterioration from any cause. In the inspection of refrigerators, special attention should be devoted to the detection of undesirable odors, excessive moisture, or the presence of spoiled food. The methods of storing food in the refrigerator should also be noted (page 564).

Inspection of food supplies. The inspection of a mess should include inspection of the food supplies in the mess. The condition of the food supplies in this respect will indicate the character of the food issued to the mess and the efficiency with which it is handled and stored after receipt. Particular attention should be given to fresh meat, fresh vegetables and bread. If deemed desirable, a piece inspection may be made of the canned foods in the mess.

Menus. The menus should be studied with a view to determining if a balanced ration is served (page 413) and if the ration as served is sufficiently varied and is acceptable to the group appetite. The filed menus for a number of previous days, or menu periods, should be investigated. The inspector should also be present during the serving of at least one meal and note whether the articles named in the published menu are actually served.

Methods of preparing food. The methods employed in preparing the food should be investigated for the purpose of detecting defects which would result in contamination of the food. Particular attention should be given to the manner in which cooked food is handled and stored prior to serving and to the methods used in preparing raw vegetables, salads or other dishes that are especially liable to transmit infection.

Methods of serving food. The method of serving the food to the troops should be studied with a view to searching out deficiencies or defects which would impair the acceptability of the ration, decrease its appeal to the group appetite, or which might

result in contamination of the food. The actual condition of the food as it reaches the troops should be observed, such as, for example, the appearance of the food, or whether hot foods are actually served hot. Where line service is used, the appearance and condition of the food on the serving tables should be noted.

Food handlers. The inspector should determine whether or not each permanent food handler has been certified by the surgeon as free from communicable disease. The degree to which the health of all food handlers is observed and supervised by the mess officer or organization commander, and the action taken when a food handler presents symptoms of illness should be ascertained.

The personal cleanliness of all food handlers should be noted. The inspector should also determine if the food handlers have been properly trained in personal cleanliness and methods of preventing the transmission of disease, and whether suitable rules and regulations with regard to the maintenance of personal cleanliness are properly enforced.

Action taken to correct defects. The inspector may make his recommendations for the correction of defects either to the mess officer or, in the case of a company mess, to the organization commander, or to higher military authority, such as the station commander or the regimental commander. Usually, the correction of minor defects can be obtained by consultation with the officers directly responsible for the operation of the mess. Major defects and all deficiencies which cannot be, or are not, corrected by the officer in charge of the mess should be reported to the next higher military authority with recommendations for correction.

Following inspections during which defects were found and corrective measures recommended, reinspections should be made at the proper time to determine if, and to what extent, approved corrective measures have been instituted.

CHAPTER XIII.

WASTE DISPOSAL

GENERAL FEATURES—SEWAGE DISPOSAL

Waste disposal, for the purpose of preventing the spread of disease, is the removal, destruction, or control of those waste materials which serve directly or indirectly as agencies for the transfer of disease producing organisms from person to person.

The wastes which are factors in the spread of disease are:

a. Human excreta (feces and urine).

b. Garbage.

c. Liquid wastes (waste water from kitchens, baths, wash tables or laundries).

d. Manure.

The Quartermaster Corps is responsible for the disposal of waste materials and for the construction, operation and maintenance of all permanent facilities and installations utilized for waste disposal by two or more units. Unit commanders are responsible for proper disposal of waste within the areas occupied by their units and are, therefore, responsible for the construction, operation and care of all temporary or emergency appliances employed by their units for the disposal of wastes.

SANITARY CONTROL BY THE MEDICAL DEPARTMENT

The Medical Department is responsible for the sanitary supervision and inspection, and for reporting upon and making recommendations pertaining to the construction and operation of all facilities and installations employed for the disposal of those wastes which are directly or indirectly concerned in the transmission of disease.

The scope of the sanitary control exercised by the Medical Department includes the following activities:

a. The sanitary survey of sites and the study of plans for proposed waste disposal facilities of a permanent nature.

b. Surveys and inspections of existing permanent waste disposal installations for defects in construction or operation which are of sanitary significance.

c. The formulation of recommendations relative to the installation of temporary appliances, or the adoption of emergency measures, for the disposal of waste material inimical to the health of the troops.

d. The sanitary supervision and inspection of existing temporary or emergency facilities for waste disposal.

e. The laboratory analysis of sewage and sewage effluents.

SANITARY SIGNIFICANCE OF WASTES

Wastes influence the health of man either by transmitting pathogenic organisms directly to food or water to be consumed by man, or indirectly by providing breeding places or food for house flies.

Human excreta. Human excreta is the only waste material that contains pathogenic organisms under normal conditions and is, therefore, the only waste which serves as a direct source of pathogenic organisms. The causative organisms of most of the intestinal diseases are eliminated from the body in the feces, and in some instances also in the urine, and are transferred to the alimentary tract of susceptible individuals by contaminated food or water.

Food may be contaminated with the causative organisms of an intestinal disease by infected excreta from the hands of those sick with the disease in question or who are carriers of the organisms. The house fly (*Musca domestica*), because of its tendency to breed in human feces, may serve to transfer, mechanically, pathogenic organisms from the feces to food. Water which is to be used for domestic purposes may be contaminated, or shellfish taken from water which is contaminated with sewage may carry pathogenic organisms to man. Consequently, in order to prevent the transfer of pathogenic organisms from human excreta to the alimentary tract of susceptible individuals, the excreta must be disposed of or treated in

such a manner that it will not contaminate water which is to be consumed in an unpurified state or from which shellfish are obtained, nor be carried to the food of man by flies or on the hands.

Garbage, liquid wastes and manure. Garbage, liquid wastes and manure do not ordinarily contain the causative organisms of disease, but are factors in the spread of disease in that they provide breeding places or food for the house fly, or serve to attract flies to the vicinity of kitchens or mess halls.

Nuisances. A nuisance is defined as anything that is offensive to the senses, dangerous to life, or renders the soil, air water or food unwholesome or impure. Human excreta, garbage, liquid wastes and manure are putrescible substances which will, under certain conditions, create nuisances consisting of disagreeable odors, unsightly accumulations or large numbers of flies. In the practical application of waste disposal measures, the primary objective is to prevent the transmission of pathogenic organisms, but the methods employed, if they are to be efficient and enforceable, must also preclude the creation of nuisances. In most instances, it is more difficult to prevent the occurrence of nuisances than it is to prevent the transmission of pathogenic organisms, and for this reason the methods employed in the disposal of wastes are principally those that will prevent, or reduce to a minimum, the creation of nuisances, and incidentally control the transmission of disease-producing organisms from the waste materials to man.

SEWAGE DISPOSAL

Where a piped water supply and a sewerage system are available, human excreta, together with certain other waste materials, is disposed of as sewage. Sewage disposal procedures include the collection of sewage by a plumbing system in the buildings where it is produced; the transportation of the sewage by water carriage through sewers and drains; the operation of sewage treatment works and the final disposal of the effluent from sewage treatment works or, in the absence of treatment, the final disposal of the raw sewage.

All sewage must be ultimately disposed of by discharge into a body of water or by irrigation in or on the soil. Disposal by dilution in water is the most common method, as it is

seldom feasible to dispose of sewage by irrigation. The raw sewage may be disposed of directly by dilution in water or by irrigation, or it may be necessary to subject it to prior treatment in order to prevent the production of nuisances and obviate danger to the health of man.

Composition of sewage. Sewage consists essentially of the used water supply of a community containing certain of the dissolved or suspended waste materials produced by that community. These wastes are human excreta, bath water, liquid kitchen wastes, drainage from shops, laundries, stables, etc. The sewage produced by civilian communities may also contain industrial wastes from manufacturing plants.

The volume of sewage produced approximates that of the water delivered, provided that there is no considerable quantity of leakage of water from the soil into the sewers. The usual quantity of sewage to be disposed of at a camp or station varies from 50 to 100 gallons per capita per day, depending upon the amount of water wasted in plumbing fixtures, restrictions on the use of water, and the quantity of ground and surface water which flows into the sewers.

The amount of sewage produced by a camp or station varies hourly during the day according to the activities of the troops. The greatest flow occurs during the period from reveille until the troops are turned out for drill or fatigue, when the hourly flow is usually from 50 to 100 per cent more than the average per hour during the 24 hours. The flow is again increased during the period between evening mess and 8 or 9 o'clock P.M., when the hourly rate is usually from 25 to 75 per cent greater than the average hourly rate for the 24 hours. The minimum flow occurs between midnight and reveille.

The proportion of solid material in sewage is modified considerably by the quantity of water which enters the plumbing fixtures or leaks into the sewers. Ordinarily, the sewage from military stations and camps contains from 600 to 1200 parts per million of suspended and dissolved solids. About 50 per cent of the solid material is mineral and about 50 per cent is organic. Of the total, about 38 per cent is suspended and about 62 per cent is dissolved. About 50 per cent of the suspended solids, or 19 per cent of the total solids, will settle out in the two hours required by the settleable solids test (page 711).

The raw sewage from a military station or camp is more concentrated than that produced by a residential civilian community and contains comparatively larger quantities of fecal substance, paper and debris and grease from the kitchens.

PLUMBING

The plumbing system consists of the pipes and fixtures which carry the water into a building and those which collect and carry away the wastes from toilets, baths, kitchens, wash bowls and sinks. The plumbing system terminates where the house drain joins the house sewer (page 601). The essential features of that part of the plumbing system which collects the waste materials are the fixtures with their connecting lateral pipes, the soil stack, waste stack, vent stack or pipe, and house drain.

Stacks. The stacks are vertical pipes, usually three or four inches in diameter, which extend from above the roof vertically downward through the building to the house drain on or below the floor of the building or basement. The soil stack receives the drainage from the toilets and urinals, and the waste stack from all other fixtures. The drainage from all fixtures may empty into one stack known as the drainage stack. The stacks equalize the air pressure throughout the system and provide ventilation which prevents the accumulation of gases in the pipes.

Traps. Each fixture is equipped with a trap so constructed that it is sealed with water, except when the accumulation of water in the fixture, or in the pipes leading from the fixture to the trap, becomes sufficient to break the seal and convert the trap into a siphon. The waste passes from the trap through a horizontal soil or waste pipe to the stack (Fig. No. 153). The trap serves to prevent the gases, which might be formed in the pipes leading from a fixture, from passing back into the room in which the fixture is installed.

Vents. In order to prevent unsealing of the traps, each soil or waste pipe is connected with a vent pipe immediately behind the trap it serves (Fig. No. 153). The vent equalizes the air pressure throughout the system so that at no time is there sufficient variation in pressure, either positive or negative, to force or draw the sealing water out of the trap. If the

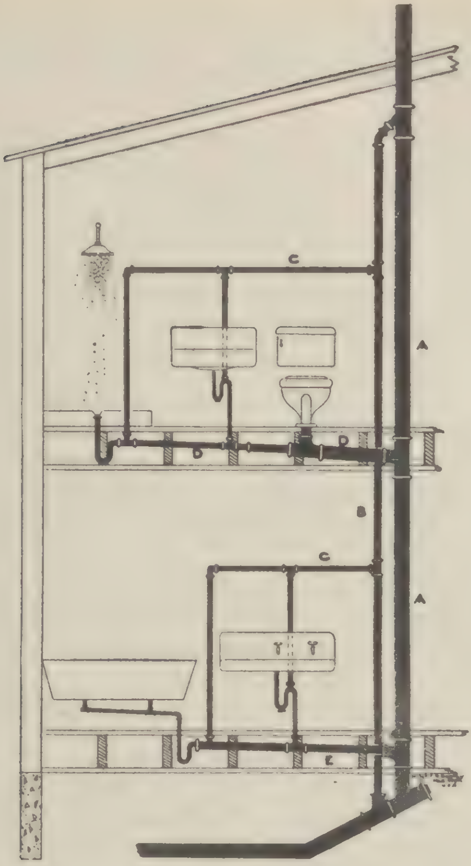


FIG. No. 153. A plumbing system for barracks (Schematic). A—Drainage stacks. B—Vent stack. C—Vent pipes. D—Soil pipes. E—Waste pipes.

waste or soil pipe is not properly vented, the discharge from another fixture into the stack may create sufficient suction to pull the water out of the trap. If the water from the trap flows through a poorly vented pipe, the velocity of the discharge may be sufficient to pull all the water out of the trap. The water flowing from a higher fixture may produce sufficient air pressure in the stack and the pipe to blow the water out of a trap which has no vent. The vent pipes from the different fixtures open into a vent stack which rises parallel to the drainage stack and may be connected with it above the highest fixture (Fig. No. 153). The vent pipe should open into the soil or waste pipe

at a distance of not more than five feet from the trap, as a horizontal flow of more than this distance through an unvented pipe will frequently create sufficient suction to break the seal in the trap.

House drains. House drains are horizontal drain pipes which receive the sewage from the soil and waste stacks in basements, cellars or under buildings. They usually connect with the house sewers about five feet outside the foundation walls of the building. In order to prevent stoppage and leakage into the soil under buildings or flooding of basements or plumbing fixtures, a house drain should have a minimum diameter of not less than four inches, and a minimum fall of one-fourth inch per foot. It should be so installed that it is firmly supported and will not be cracked or broken by the settling of the building. There should always be one or more cleanout holes so located inside or outside the building that a cleaning rod or wire can be employed to locate and remove material causing stoppage.

Sanitary features of plumbing. Sewer gas which is formed by the decomposition of putrescible substances in pipes and sewers is not a factor in the transmission of disease. It does, however, create a nuisance when it escapes through defects in the plumbing into an inhabited building. The entire plumbing system of a building should be so vented and trapped that no gas will escape through the fixtures and so constructed that there is ample ventilation throughout the system. The pipes should be of such size and so installed that normal usage will not cause clogging of the pipes with consequent flooding of the fixtures. All sinks should be equipped with strainers having holes not more than $\frac{1}{4}$ inch in diameter in order to prevent large pieces of solid material from entering the waste pipes and clogging the traps or pipes. The pipes from kitchen sinks should be equipped with grease traps.

SEWERAGE SYSTEMS

A sewerage system consists of sewers which receive the sewage collected by the plumbing systems of the buildings served. These sewers may also collect storm water from roofs, roads and streets. If the sewers carry only sewage, they are known as sanitary sewers. Sewer lines which carry only

storm water are known as storm drains or storm sewers. Sewers which carry both sewage and storm water are called combined sewers.

Where one system of sewers is installed for draining away the storm water and another system is employed to carry sewage, the sanitary sewers and the storm drains together form what is known as a *separate* sewerage system. If the storm water is carried in the same sewers as the sewage, the system of sewers is called a combined sewerage system. As a rule, separate sewerage systems are installed in military stations and camps, and storm water drainage is accomplished by the use of separate drains, gutters or ditches.

House sewers. The house sewer, or house connection, is the sewer connecting the house drain (page 600) with the common or lateral sewer. It should be not less than four inches, and preferably six inches, in diameter and laid with a minimum grade of one-fourth inch per foot.

Lateral sewers. A lateral sewer is the sewer in the street or road into which the house sewers empty. The upper end of a lateral sewer is known as the dead end. The lower end joins a sub-main or branch sewer. In order to minimize the danger of clogging and to facilitate cleaning, lateral sewers should be at least eight inches in diameter and there should be no change in grade or direction between manholes.

Sub-main or branch sewers. A sub-main or branch sewer is a sewer which receives the flow from two or more lateral sewers. The lateral sewers may be joined directly to a branch sewer or the sewage may pass from a high lateral to a lower branch sewer through a drop manhole.

Main or trunk sewers. A main sewer is a sewer into which two or more branch sewers empty and constitutes the principal stem of the sewer system. There is usually only one main sewer in a small station or camp, but in the larger installations, or where the topography of the terrain is such that not all of the buildings can be drained into one main or sewer, there may be two or more main sewers.

Intercepting sewers. An intercepting sewer is a sewer that is laid transversely to and receives sewage from two or more main sewers. Intercepting sewers may form a part of either a separate or combined sewerage system. When employed in a combined system, the intercepting sewer intercepts

and carries away from the main sewers all of the dry weather flow of sewage and a predetermined proportion of the wet weather flow consisting of sewage mixed with storm water. The excess wet weather sewage overflows from the intercepting sewer through a regulator into an outfall sewer which conveys it to a place of disposal.

The purpose of an intercepting sewer of a combined system is to prevent the overloading of the sewage treatment works by providing a means of disposing of a part of the excess sewage produced by storm water. Ordinarily, the sewage which overflows from the intercepting sewer through the regulators into the outfall sewers is not treated but is disposed of by dilution (page 605) in a convenient body of water, or possibly by irrigation in a dry ravine or on waste land. Although the overflow sewage is highly diluted with storm water, it contains much excreta and other putrescible material. Consequently, the intercepting sewer of a combined sewerage system may produce conditions inimical to health where the sewage from outfall sewers is disposed of directly or indirectly in water used for drinking, bathing, or from which oysters are taken.

Intercepting sewers may be used to collect the sewage from sanitary main sewers above a certain level so that a part of the sewage can be transported to the point of disposal or to sewage treatment works by gravity, while other trunk or intercepting sewers are employed to convey the sewage from lower levels to pumping stations. These intercepting sewers are in reality main sewers which are laid transversely to other main sewers. As they do not carry storm water, there is no overflow of excess sewage into outfall sewers.

Outfall sewers. An outfall sewer is a sewer which conveys the sewage from the lower end of a main sewer, or an intercepting sewer, to the place of final disposal or to a sewage treatment plant.

Sewer appurtenances. Sewer appurtenances are the parts, devices, or appliances, such as manholes and flush tanks, which with the sewers form the sewerage system.

Manholes. A manhole is a vertical shaft, usually about three or four feet in diameter, which leads from the surface of the ground down to the sewer and which permits access to the

sewer for cleaning and inspection purposes. The walls of the manhole are usually made of brick or concrete.

Manholes are located on the sewer line wherever there is a change in the grade or alignment of the sewer, unless the sewer is large enough to permit the passage of a man. Manholes on small sewers need not be located less than 200 feet apart, but in order to facilitate cleaning with a rod or by flushing, the distance between two manholes should not be more than 300 feet where the sewer is less than 18 inches in diameter, nor more than 400 feet in larger sewers.

A drop manhole is a manhole in which the sewage falls vertically from one sewer to another at a lower level. Where the distance through which the sewage falls is considerable, such a manhole is also known as a wellhole.

Every manhole should have a tight fitting cover to prevent the wilful or accidental deposition of debris in the sewer. The manhole cover is usually made of iron and may be provided with a lock.

Flushing devices. At times the topography of the ground in relation to the buildings is such that the lateral sewers must be laid on a very flat grade. Because of the flat grade, the small quantity of liquid entering the laterals does not flow with sufficient velocity to prevent the deposition of suspended matter. Consequently, there is a constant tendency for the sewers to clog, necessitating cleaning at more or less regular intervals. The most common method of cleaning such sewers is by flushing with water under sufficient pressure to carry the deposited material to a point in the sewer system where the velocity of the normal flow is sufficient to preclude further settling. This may be accomplished by the use of a fire hose when only occasional flushing is necessary, but automatically operated flushing devices are desirable where flushing at regular intervals is required.

Flushing manholes. A flushing manhole may be installed by running a small service pipe from a nearby hydrant to the manhole and closing the sewer leading from the manhole with a plug, or a trip or gate valve. When a predetermined amount of sewage together with water from the service pipe has accumulated in the manhole, the plug is drawn out or the valve tripped, automatically or by hand, and the water allowed to flow rapidly through the sewer.

Flush tanks. Flush tanks of requisite capacity may be installed at the dead ends of lateral sewers. These tanks discharge periodically through a simple siphon which is usually so adjusted that the desired amount of water or sewage is discharged into the sewer once in every 24 hours (page 678). Ordinarily, from 300 to 400 gallons of water are sufficient to flush a small sewer.

Sanitary features of sewers. As the function of a sewerage system, from the viewpoint of disease and nuisance control, is to transport all the sewage away from the vicinity of human habitation, any condition or factor which precludes the efficient performance of this function is of sanitary significance. Any defects in construction or faulty operation which will permit the escape of sewage from the sewers before the place of disposal is reached may ultimately result in the transmission of disease to man or in the production of a nuisance.

Velocity of flow. The velocity of flow should be great enough to prevent the suspended solid material from settling out in the sewers. The velocity is determined by the grade, the size of the pipe and the depth of the fluid in the pipe. If the size of the sewer and the grade are constant, the flow will reach its maximum velocity when the sewer is between 0.8 and 0.85 full. The velocity in a sewer which is one-half full is the same as that in a sewer which is full.

In practice, a minimum velocity of 2 feet per second, when the sewer is full or half full, is required to prevent the formation of deposits in a sanitary sewer, and a greater velocity is usually desirable. To attain this minimum velocity, a 4-inch pipe must have a fall of 1.2 feet in 100 feet; an 8-inch pipe, 0.4 foot in 100 feet; a 12-inch pipe, 0.22 foot in 100 feet, and a 24-inch pipe, 0.08 foot in 100 feet.

If the velocity of the flow is not sufficient to move the heavier suspended matter, deposits will form which will clog the pipes and cause flooding of manholes, basements or plumbing fixtures. When the low velocity is due to a flat grade, or a small quantity of sewage, provision should be made for cleaning by emergency or periodic flushing.

Leakage. The quantity of ground and surface water which enters the sewers through defective pipes, joints and connections, and through and around the manhole covers, varies from 5000 to 100,000 gallons per mile of sewer per day. The leakage of water

into new and well constructed sewers or those having comparatively few connections to buildings is much less than in the case of older installations or sewers serving numerous buildings. If there is considerable leakage of ground and surface water into the sewers, the cost of treating the sewage will be proportionately increased or the efficiency of the treatment will be decreased.

Sewage may leak out of the sewers through breaks in the pipes, or defective connections, into the surrounding soil where it may contaminate ground water supplies or be conveyed directly or indirectly to the food or drink of man.

DISPOSAL BY DILUTION

Raw sewage, or the sewage effluent from treatment works, is disposed of by dilution in a body of natural water under conditions which will result in the dispersion of the settleable solids and the oxidation of the organic matter by the action of aerobic bacteria. The disposal of raw sewage by dilution without other and prior treatment is an effective method where the diluting water contains sufficient available oxygen to supply the biochemical oxygen demand (page 608) of the sewage and where the quantity of diluting water or currents will prevent the formation of deposits or accumulations in which organic matter will undergo anaerobic decomposition. If the body of water available for the disposal of sewage by dilution does not meet these requirements, then the sewage should be treated prior to discharge into the water so as to decrease the biochemical oxygen demand, or reduce the quantity of settleable and floating solids to an extent which will permit disposal by dilution without the creation of a nuisance. Except where the sewage is finally disposed of by broad irrigation (page 610), all sewage treatment procedures are preliminary to and serve to prepare the treated sewage for final disposal by dilution.

Principles of disposal by dilution. When sewage is discharged into a body of water which is suitable for the disposal by dilution of the sewage in question, certain definite changes occur. The unstable organic matter is oxidized by the action of aerobic bacteria. The heavy settleable solids, such as the mineral matter, are dispersed by the currents and eventually settle out over a wide area. Grease, paper and various other

kinds of floating debris are carried away and do not form unsightly accumulations.

If the water into which the sewage is discharged is insufficient in quantity or is too quiescent to effect adequate disposal of the sewage by dilution, nuisances will be produced. The settleable solids will form deposits on the bottom and banks. The aerobic bacteria exhaust the supply of available oxygen and anaerobic decomposition of the remaining organic matter with the production of noxious gases takes place. The floating substances are not carried away, but remain to form unsightly accumulations on the surface.

Interests of civilian population. In military establishments the sewage is transported through the sewers away from barracks and quarters to a more or less distant point for treatment or disposal. If the sewage is treated in a Government owned treatment works, the plant is usually on the military reservation. The point at which raw or treated sewage is discharged into a body of water for final disposal may or may not be on the military reservation, but in any event the sewage is usually carried by the water into civilian communities and comes in contact with civilian owned property. Consequently, it frequently happens that civilian rather than military interests are jeopardized by sewage from military stations or camps.

Civilian communities and property may be injured by sewage from military establishments through gross contamination of water supplies or bathing beaches, or by damage to shellfish industries. Local nuisances, such as odors or accumulations of sludge produced by a sewage disposal plant or by a stream overloaded with decomposing organic matter, may be a just cause of complaint by local residents and may cause depreciation in the value of nearby civilian property. Where the stream into which the sewage is discharged flows through an agricultural section, the presence of sewage in the water may markedly decrease its value for farm use.

Riparian rights. A riparian owner, or proprietor, is one who owns land bounded by or containing a stream or other body of water. Riparian rights are the rights which accrue to a riparian owner as to the use of the water which bounds, flows through or is contained within his land.

Riparian rights, as interpreted in most states, are based on common law principles to the effect that, first, every riparian owner has the right to make reasonable use of the water concerned, and second, that every riparian owner is entitled to have the water reach his property in a natural and unpolluted state, except for conditions which may have resulted from reasonable use by other riparian owners. Reasonable use of water, as interpreted under common law, is use for watering stock, bathing, washing, irrigating land and other agricultural purposes. With the growth of industries other than farming, the courts have made other interpretations so that each case must, as a rule, be decided on its merits. However, it is a well established principle that where sewage is discharged into water in amounts that will definitely impair the quality of the water, riparian owners are entitled to obtain damages and injunctions.

Where the rights of a riparian owner are, or will be, impaired by the discharge of sewage from a military establishment into a body of water, the courts may award damages, or grant an injunction preventing continuance of the pollution or forbidding the discharge of sewage into the stream. In some instances, it may be necessary for the Government to purchase the property concerned.

Cooperation with local governmental agencies. Most of the states have laws and regulations governing the disposal of sewage in water, or on or in the soil. While state laws are not operative on a military reservation, they do operate where the effect of acts performed on federal ground extend beyond the limits of the federal reservation into territory under the jurisdiction of the state. Thus, the discharge of sewage into a stream on a military reservation in a way that is a violation of a state law becomes an act of which the state courts may take cognizance when the stream enters state territory. Medical Department officers should be familiar with the state, county or municipal laws and regulations governing the disposal of sewage in their locality and should consider such laws and regulations when making recommendations pertaining to the operation or installation of sewage disposal systems.

Dissolved oxygen content of the diluting water. All natural waters contain dissolved oxygen in proportions which vary within limits, principally with the temperature, but also to

some extent with the winds, currents and quantity of vegetation in the water. Cold water contains a larger proportion of oxygen than warm water. At 10°C. (50°F.) water will hold 11.31 parts per million of oxygen; at 20°C. (68°F.), 9.19 parts per million, and at 30°C. (86°F.), 7.5 parts per million. The oxygen which is dissolved in the water is derived largely from the atmosphere and, therefore, the re-aeration of water from which the oxygen has been partially exhausted proceeds much more rapidly when the surface is agitated by wind or by currents than from a quiet surface. Consequently, other factors being equal, the available oxygen content is exhausted much more quickly in quiet water than in flowing water.

The oxidation of unstable organic matter into stable organic and mineral compounds is accomplished by aerobic bacteria. As long as the water contains oxygen, aerobic bacterial activity continues, the development of anaerobic bacteria is inhibited, and no putrefaction, and hence no nuisance due to odors, occurs.

The biochemical oxygen demand of the sewage. A given quantity of organic matter in sewage requires a definite amount of oxygen for the growth of the aerobic bacteria required to accomplish complete stabilization. This constitutes the biochemical oxygen demand of the sewage, which is expressed as parts per million of oxygen required for the stabilization of the organic matter by aerobic bacterial action.

The biochemical oxygen demand varies with the character of the sewage and, to some extent, with the temperature, being higher in the summer than during the colder months. The demand of average raw sewage varies form 100 to 200 parts per million. Average tank treatment will reduce the biochemical oxygen demand of raw sewage from 30 to 50 per cent; filtration through a trickling filter will effect a reduction of from 60 to 80 per cent in the demand of tank effluent, and sedimentation of the trickling filter effluent in secondary sedimentation tanks will produce a further reduction of from 3 to 5 per cent. Thus, typical tank and trickling filter treatment will reduce the biochemical oxygen demand of the raw sewage from 75 to 85 per cent, or given raw sewage having a biochemical oxygen demand of 150 parts per million, the final effluent will require about 30 parts per million of

oxygen to produce stabilization. Whenever the dissolved oxygen content of the diluting water is insufficient to meet the biochemical oxygen demand of the sewage discharged into it, anaerobic decomposition of the organic matter will occur as soon as the oxygen in the water is exhausted.

The volume of diluting water required. In order to effect decomposition and stabilization of sewage by dilution without the production of nuisances, there must be sufficient diluting water to supply the oxygen required to promote and maintain aerobic bacterial activity. The volume of diluting water required to dispose properly of raw sewage depends somewhat on the concentration of the sewage, the temperature of the water, and the presence or absence of currents and the velocity of the currents. Under average conditions, there must be a minimum of between forty and fifty gallons of diluting water for each gallon of raw sewage. Stated in another way, a flow of not less than six to eight cubic feet of diluting water per second, or four to five million gallons per day, is required to dispose of the raw sewage produced by 1000 persons. The volume of diluting water required for the disposal of effluents from sewage treatment works depends on the extent to which the biochemical oxygen demand of the sewage is reduced by treatment.

Methods of disposal by dilution. An outfall sewer or outlet pipe carries the raw sewage from the main or trunk sewer, or the effluent from a sewage treatment works, to the outlet, which is the point of discharge into the body of water utilized for dilution. The outlet should be placed so as to obtain the maximum dispersion of the sewage by surface currents or by submergence. If the sewage is to be discharged into the quiescent waters of a lake or bay, the outlet should be well submerged at a point as far as practicable from the shore. If the sewage is to be discharged into a rapidly flowing stream, the outlet may be near or at the shore and need not be submerged, provided the sewage enters the water at a point where the currents will cause rapid dispersion.

DISPOSAL BY IRRIGATION

Disposal by irrigation is accomplished by applying the sewage to the soil so that the liquid portion is absorbed into and carried away by the ground water and the organic constituents are stabilized by the nitrifying bacteria. The type of soil selected for disposal by irrigation must be such that the liquid is readily absorbed. Dry sand or loam is the best for this purpose and impermeable soils, such as clay or water soaked earth, are useless. The large area required and the danger of contaminating ground water which might be a source of drinking water, or of creating nuisances, usually render irrigation impracticable as a method of sewage disposal for military establishments.

Two general methods of irrigation are employed. These are broad irrigation and sub-surface irrigation.

Broad irrigation. Broad irrigation is the process of applying sewage to the surface of the land so that it will fertilize and water the soil, while the excess liquid is carried away by the ground water. It may be distributed in ditches or furrows or allowed to flow over the ground. Disposal rates vary according to the character of the soil and the amount of rainfall, from about 3000 gallons per acre per day in soils containing a large proportion of clay to 30,000 gallons per acre per day in loam with a sand or gravel subsoil. Over-dosage will cause pooling and nuisances.

Sub-surface irrigation. Sewage may be carried into the upper layer of the soil in open joint, tile pipes for disposal by sub-surface irrigation. Under suitable conditions, this is a satisfactory method for disposing of the effluent from the small treatment plants (page 715).

CHAPTER XIV.

SEWAGE TREATMENT

Where raw sewage cannot be disposed of by dilution or irrigation without the production of nuisances or endangering the health of man, such sewage must be treated prior to final disposal. The method of treatment adopted will depend on the degree of purification required by local conditions. Generally, all treatment measures involve the removal of a part of the settleable solids from the sewage and subsequent treatment or disposal of both the removed solids and the remaining liquid with its retained solids so that each is rendered innocuous under existing local conditions.

The decomposition of the organic matter in sewage is accompanied by chemical changes due to the activities of living organisms. These organisms are chiefly bacteria, but also include protozoa, plankton and helminths. Under certain conditions, as in septic tanks or in streams overloaded with sewage, no oxygen is available and decomposition is caused by anaerobic bacteria and characterized by the production of foul gases. Where the required amount of oxygen is present, as for example when sewage is treated in trickling filters or by the activated sludge method, the decomposition or oxidation of the unstable organic matter is accomplished by the action of aerobic organisms without the production of obnoxious gases.

Procedures employed in the treatment of sewage. The selection of a method of sewage treatment for a given military station or camp is governed by local conditions and requirements. As all sewage must ultimately be disposed of by dilution in water, or by irrigation in or on the soil, the object of any method of treatment utilized is to modify the character of the sewage so that it can be safely disposed of in the water

or soil available for that purpose. Consequently, each of the different procedures employed is designed to promote the decomposition of the organic matter by anaerobic or aerobic organisms under controlled conditions.

Sewage treatment procedures may involve only the removal of the floating substances and a greater or less proportion of the settleable solids, so as to prevent the formation of unsightly floating accumulations or extensive deposits. Where the available oxygen content of the diluting water is not sufficient to satisfy the biochemical oxygen demand of the raw sewage, the amount of organic matter in the sewage is reduced and the remainder partially stabilized by treatment prior to disposal of the effluent by dilution. Under certain conditions, it may be necessary to disinfect the effluent from sewage treatment plants to prevent the contamination of water supplies, bathing beaches or shellfish. In any event, the treatment of sewage by whatever method is employed is carried only so far as may be necessary to protect the health of troops or civilian inhabitants of the locality, and to prevent nuisances under conditions existing at the station or camp in question.

The following procedures are employed separately or in combination in the treatment of sewage:

Screening	Activated sludge method
Plain sedimentation	Trickling filter treatment
Septic tank treatment	Contact bed treatment
Imhoff tank treatment	Intermittent sand filtration
Separate sludge-digestion	Chlorination
Chemical precipitation	

Sewage treatment works. A sewage treatment works or plant consists of one or more of the several installations employed in the treatment of sewage, the nature of which depends on the method of treatment adopted. A typical plant may, for example, consist of screens, grit chambers, sedimentation tanks, separate sludge-digestion tanks, sludge beds and a trickling filter with the necessary pumps, by-passes, buildings, etc., and, in some instances, appliances for disinfecting the sewage.

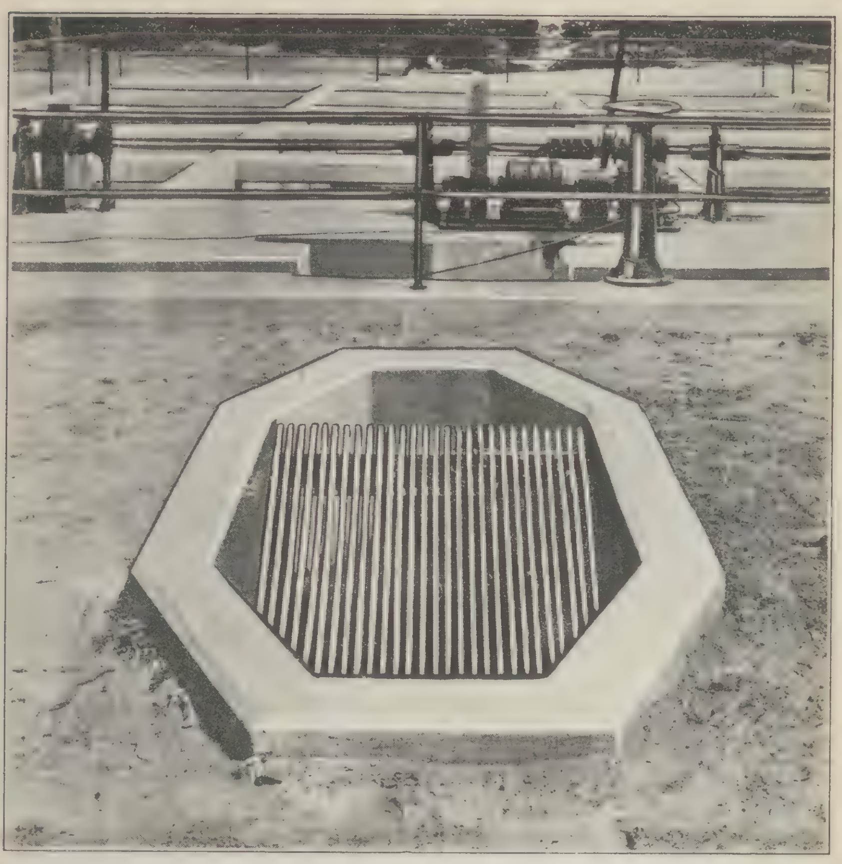


FIG. No. 154. Bar screen. (Courtesy of the Link-Belt Company, Philadelphia, Pa.).

SCREENING

Raw sewage may be passed through screens of various kinds and sizes to remove a part of the suspended solids. Screening may be the only treatment used prior to final disposal, or screens may be employed solely to remove substances which would injure pumps or other mechanical appliances.

Coarse screening. Coarse screening is the process of removing floating material and coarse substances which might interfere with the operation of pumps, form unsightly accumulations on the surface of the water used for disposal by dilution, or produce scum in treatment tanks. As coarse screening will remove only relatively large size material, it is not a treat-

ment measure in the sense that it modifies to any considerable extent the chemical or biological characteristics of the sewage. Ordinarily, it is employed only as a means of removing material which would interfere with the execution of other sewage treatment measures.

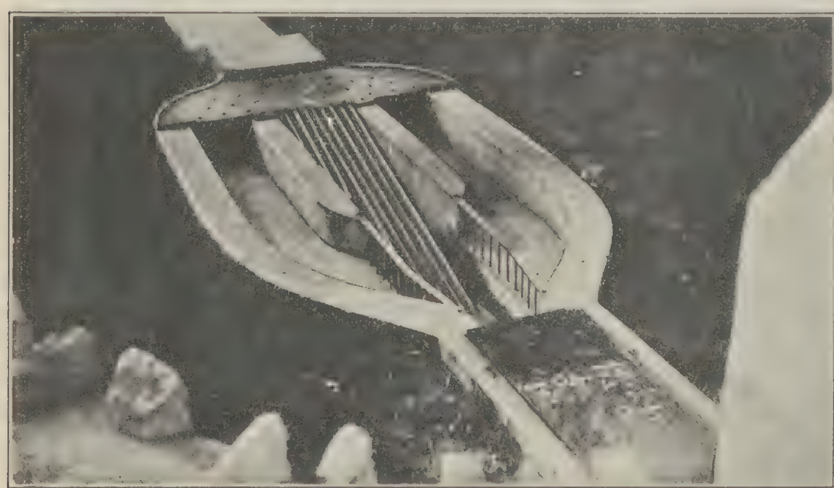


FIG. No. 155. Bar screen for a small installation.

The amount of material removed as screenings by coarse screens depends largely on the size of the openings in the screen, and to some extent on the character of the sewage. It varies from one-half to four to six cubic feet, or from about 25 to 300 pounds, per million gallons of sewage. Because of the nature of the material removed, the amount cannot well be expressed in parts per million.

Coarse screens usually consist of parallel iron bars so placed that the sewage flows between them. The bars are one-fourth to one and one-half inches apart, the distance between them depending on the kind of material that they are designed to remove from the sewage. Where the purpose of the screen is to protect pumps, the openings are usually one-half inch. Ordinarily, the bars are about one inch apart if the sewage is to be disposed of by dilution without further treatment. Larger openings may be employed where it is desired only to prevent coarse floating material from entering treatment tanks.

Coarse screens may be either fixed or movable. The fixed screen is the most common installation and consists of a rack of parallel bars placed in a channel through which the sewage flows. The rack is placed at an angle of about 30 to 50 degrees from the vertical in the direction of the flow (Fig. No. 154). It extends entirely across the channel and from the bottom to a point well above the surface of the sewage so that all of the sewage must pass through the screen.

FIG. No. 156. Bar screens equipped for mechanical cleaning. (Courtesy of the Link-Belt Co., Philadelphia, Pa.).

Cleaning coarse screens. In the smaller plants, coarse screens are usually cleaned with long handled rakes by which the material retained on the bars is raked over the top of the screen onto a platform or into a wheelbarrow or other conveyance. The teeth of the rake should be so spaced that they fit between the bars of the screen. In the operation of larger plants, bar screens are ordinarily cleaned by mechanically driven rakes or other devices (Figures No. 156 and 159).

Fine screening. Fine screening is the process of removing from sewage with fine screens all of the coarser substances

and a part of the finer suspended solids. It is a definite treatment measure, the purpose of which is to remove a certain proportion of the suspended solids which would otherwise undergo decomposition in treatment tanks, filters, or in the water in which the sewage is to be disposed of by dilution. Fine screening will remove from 5 to 20 per cent of the suspended solids, and to this extent will modify the chemical and biological characteristics of the sewage. It is not, however, a substitute for tank treatment.

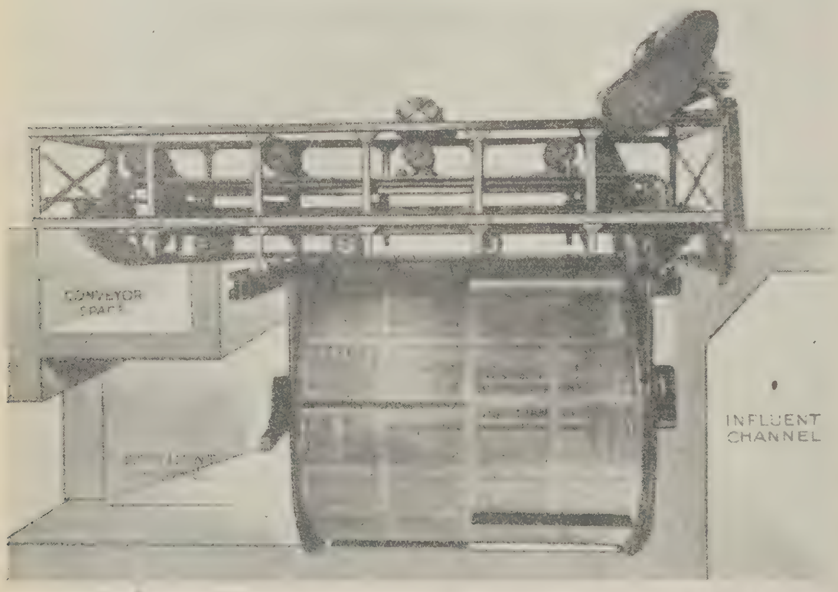


FIG. No. 157. Fine screen, rotary drum type. (Courtesy of the Link-Belt Co., Philadelphia, Pa.).

Types of fine screens. A screen having openings less than one-fourth inch in diameter is commonly classified as a fine screen. The drum screen is a cylinder, the walls of which consist of perforated metal or wire screening. The cylinder rotates on a horizontal axis so that the sewage enters one end of the cylinder and flows out through the openings in the screen. The suspended solids that are too large to pass through the openings are collected inside the drum from which they are removed by conveyer devices of different kinds. Usually, the screen consists of wire cloth varying in size from

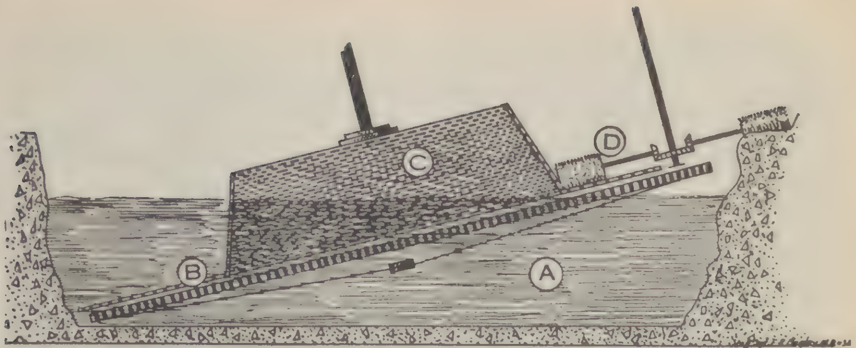


FIG. No. 158. Disc, or Riensch Wurl, fine screen (Schematic). A—Sewage in screen chamber. B—Disc of perforated plates. C—Central cone. D—Cleaning brushes.

25 to 40 wires to the inch. The screenings that adhere to the screen are loosened by jets of water from the outside.

The disc, or Riensch-Wurl, screen is a flat disc of perforated plates and may or may not have a central cone (Fig. No. 158). The screen revolves on a flat slope through the flowing sewage. The screenings are caught on the disc and carried to the upper part of the screen above the surface of the sewage, where they are swept into a gutter by mechanically operated brushes. If the screen has a central cone, the cone is also cleaned by brushes.

Disposal of screenings. If screenings are allowed to accumulate, they will produce a serious nuisance. They may be disposed of by burial, by burning or by digestion in tanks (page 645). Large indigestible articles which would clog pipes and valves must be removed from screenings before they are placed in digestion tanks.

Screenings may be ground to small particles by a mechanical apparatus and returned to the sewage for treatment as suspended solids. One such apparatus is shown in Fig. No. 159.

Operation and efficiency of screens. The efficiency of screens in removing suspended solids is dependent upon several factors. The velocity of the flow should be such that the solid matter is not broken up and forced through the screen openings. Where sewage is carried for long distances through sewers, or pumped before reaching the screens, much of the solid matter is broken and comminuted so that the efficiency of the screens is greatly reduced.

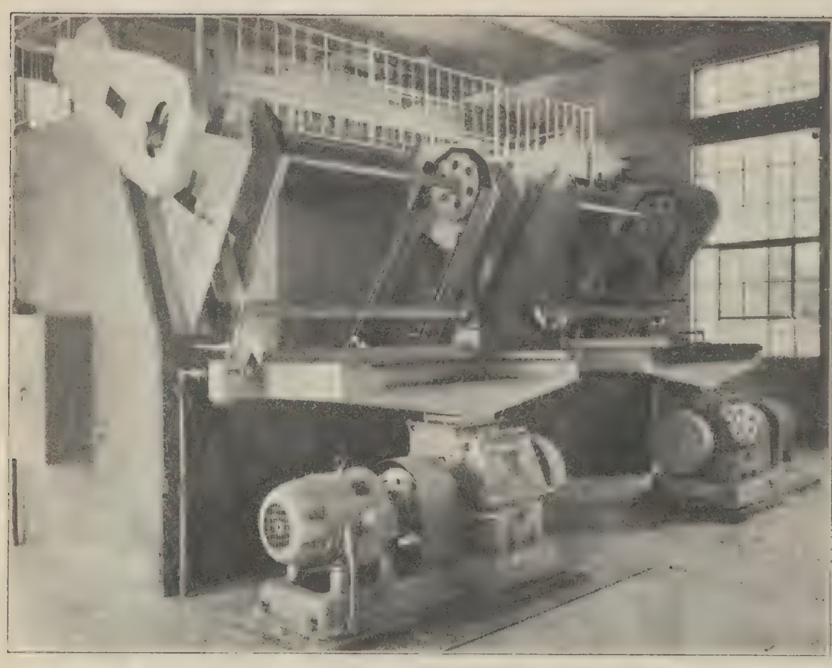


FIG. No. 159. Mechanically cleaned bar screens and screenings grinders. (Courtesy of the Jeffrey Manufacturing Co., Columbus, Ohio).

The screen chamber or channel should be so constructed that it is near the surface of the ground and otherwise readily accessible for cleaning and inspection (Fig. No. 156).

Manually cleaned bar screens should be raked at frequent intervals to prevent clogging or the forcing of solid material through the openings by the pressure of the liquid upon the screen.

SEDIMENTATION

When the velocity of the flow of sewage is decreased below a certain rate, some of the settleable solids held in suspension by the current tend to settle out and form deposits on the bottom. With the slowing of the current the heavier particles are deposited first, the others remaining suspended until lower velocities are reached or the sewage becomes quiescent. This process is called sedimentation and occurs naturally in bodies of water into which sewage is discharged for disposal by di-

lution. Under artifically controlled conditions, sedimentation can be produced in tanks. The proportion of the settleable solids which can be removed by sedimentation in tanks depends on the rate of flow, the length of the detention period, and the character of the solids. The quantity of solids deposited and the rate of sedimentation can be increased by the application of chemicals (page 649). If the deposited material (*sludge*) is allowed to undergo anaerobic decomposition in the sedimentation tank, such a tank becomes a septic tank.

Grit chambers. Grit chambers are long, relatively narrow, rectangular basins through which the sewage flows at such a rate that particles of inorganic mineral matter are deposited, while the lighter organic matter is carried through in suspension. The purpose of a grit chamber is to remove mineral matter, such as sand, or grit, prior to other treatment in order to reduce the quantity of such material which will be deposited with the sludge in treatment tanks, or to prevent damage to pumps. A large quantity of grit renders the sludge difficult to remove from the tanks and, by forming a layer on the deposited sludge, interferes with the free escape of the gas.

Grit chambers are ordinarily used only in the treatment of combined sewage, or separate sewage which contains a considerable quantity of surface washings from roads. As a rule, however, the small amount of mineral matter in separate sewage does not justify the installation of a grit chamber.

The grit chamber usually consists of two independent channels, through either of which the flow of sewage can be diverted while the other is being cleaned. Each channel forms a pit which receives and retains the deposited material. The length of the channel is governed by the sedimentation rate of the suspended mineral matter which, if the process is to be effective, must settle below the level of the outlet conduit. However, the length of each channel should be not less than three times the width.

A rate of flow of one foot per second will permit the heavier particles such as grit or other mineral matter to settle out of the fluid, while the organic matter, clay and fine sand remain in suspension. In general, lower velocities will result in sedimentation of organic matter, while a swifter flow will prevent the deposition of the mineral substances. The sewage should flow at this lowered velocity for at least one minute so that the grit will settle below the level of the outlet.

Variation in the volume of sewage produces changes in the rate of flow through the grit chamber. A grit chamber is usually designed on the basis of the average flow of sewage. Consequently, at times when the rate of flow is less than one foot per second a varying amount of organic matter will be deposited in the grit chamber.

The channel must be cleaned whenever the depth of the deposits on the bottom becomes sufficient to interfere with sedimentation. The depth of the deposits in a channel can be determined by means of a graduated rod or pole with a board or flat weight fastened transversely to one end (page 644). The flow is diverted into the other channel or, if the grit chamber consists of only one tank, through a by-pass, and the grit removed by pumps, mechanical devices or with shovels. In some of the larger plants, the grit is continuously removed from the grit chamber or channel by mechanical apparatus as shown in Fig. No. 160.

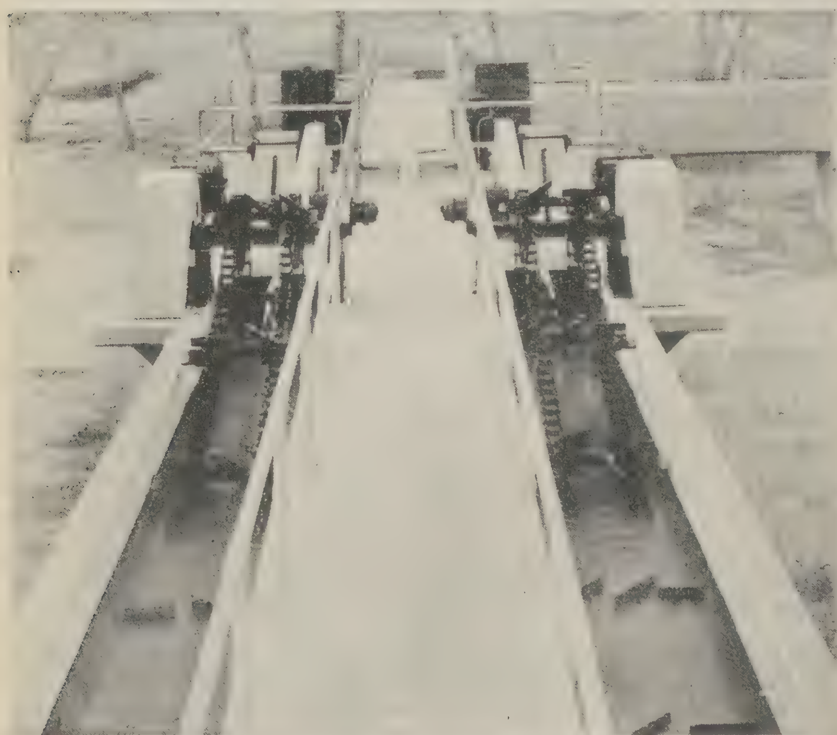


FIG. No. 160. Grit chambers with mechanical equipment for removing grit. (Courtesy of the Link-Belt Co., Philadelphia, Pa.).

If the material removed from a grit chamber contains any appreciable proportion of organic matter it should be buried or burned, in order to prevent the creation of nuisances. Burial in shallow trenches is usually a practical method of disposal at small plants.

PLAIN SEDIMENTATION

Plain sedimentation, as a method of treating sewage, involves the separation of the settleable solids from the liquid portion of the sewage and the complete removal of the sedimented material from contact with the sewage before decomposition occurs. The sludge removed from the sedimentation tank is treated or disposed of by digestion in other tanks (page 645), or by other methods (page 662).

Plain sedimentation is employed as a preliminary measure in the separate sludge-digestion method of treating sewage (page 645), in connection with the activated sludge process (page 651), and in the treatment of sewage by chemical precipitation (page 649). Plain sedimentation is also utilized in the final treatment of the effluent from a trickling filter (page 684).

The capacity, dimensions and shape of the plain sedimentation tank must be such that the velocity of the flowing sewage will be decreased and controlled to a degree which will allow the settleable solids to be deposited in the tank and also provide for the retention of the sewage in the tank for sufficient time to permit this deposition to occur. Within these limits, the capacity, dimensions and shape of the tank may vary greatly.

Design of plain sedimentation tanks. The shape of the plain sedimentation tank is determined largely by the method adopted for removing the sludge (*infra*). In some of the older plants, where sedimentation is accomplished by a fill and draw process, the tanks are shallow rectangular basins. In most of the more modern plants, the tanks are constructed for continuous flow and the sludge is removed from the tanks by mechanical devices. For example, mechanical sludge-removing apparatus such as the Dorr clarifier is designed to operate in circular tanks or in square tanks having a circular bottom. Other mechanical sludge-removing apparatus, such as the Link-Belt mechanism, is used in a rectangular tank.

In most of the plants in the United States the plain sedimentation tanks are designed for horizontal flow through the tank. Some tanks have been designed and constructed to provide for a vertical flow, while in others the sewage enters the tank at a central inlet and flows radially to the periphery of the tank (Fig. No. 166).

The depth of the tank may be determined by the means adopted for removing the sludge and is also influenced to some extent by the character of the terrain and subsoil. Because of these factors the depth varies from six to twenty feet, but it is probable that, in many instances, the effective depth will be between eight and ten feet.

The relation between the width and the length of the rectangular tank must be such as to provide the proper rate of flow and detention period. Depending upon the local conditions, the ratio of the width to the length ranges in practice from one to two to one to ten. Plain sedimentation tanks may vary in length from about thirty feet to as much as three hundred feet, but usually a tank should be at least sixty feet long. Many tanks are baffled in order to obtain the desired relation between width and length.

The relation between area and depth in the circular or square tank is determined largely by the procedure or mechanism used to remove the sludge, the nature of the terrain, the character of the sewage, the prevailing temperatures and other local factors.

The surface area is also an important factor in determining the efficiency of the tank, and ranges from one square foot per 300 gallons to one square foot per 1000 gallons of daily flow through the tank.

Inlets. The inlets of plain sedimentation tanks must be designed to reduce the velocity as quickly as practicable and to effect uniform distribution of the sewage. Usually, the inlets consist of large openings in front of which are baffles that serve to reduce the velocity and to distribute the sewage horizontally and vertically. In some plants large curved pipes are used as inlets. The sewage may be admitted to the tanks over weirs, but weirs have not proven satisfactory. The solids tend to settle out behind the weir and the sewage entering the tank over a weir is not properly distributed.

Outlets. The outlet of a rectangular plain sedimentation tank ordinarily consists of a weir. Large pipes which pass through the end wall and are submerged below the surface of the sewage may serve as outlets.

Baffles. Usually a baffle is placed in front of the inlet, or inlets, to check the flow of and distribute the sewage. Also, a baffle, or scum board, is placed behind the outlet to prevent the escape of scum in the effluent.

Longitudinal or cross baffles may be employed to equalize the flow. In any event, baffles must be carefully designed in order to avoid undue increase or changes in velocity, or disturbance of the deposited solids.

Rate of flow. The velocity of the sewage as it passes through the tank must be reduced to a point where settleable solids will be deposited and the deposited material, or sludge, will not be lifted up and carried out of the tank by currents. The rate of flow varies in different plants from 30 to 150 feet per hour. In most plants the rate of flow is between 30 and 75 feet per hour.

Detention period. The length of the detention period varies to some extent depending upon the degree of sedimentation required and the character of the sewage. Ordinarily, the sewage remains in the tank from two to three hours. Much the greater part of the settleable solids is deposited during the first two hours and but little sedimentation occurs thereafter. However, in some plants the detention period may be as long as from six to eight hours.

Sludge removal. The sludge and scum must be removed from a plain sedimentation tank before anaerobic decomposition occurs. The hydrostatic pressure exerted by the overlying sewage may be utilized to remove the sludge through sludge pipes. Where this method of sludge removal is used, the tank has a hopper bottom, or a bottom having relatively steep slopes, in order that the sludge will flow by gravity to the openings of the sludge pipes. The scum must be broken so that it will sink to the bottom of the tank, or it must be removed from the tank by other means, at intervals which will prevent septic decomposition.

In many of the plants constructed during recent years, the sludge is moved to and concentrated at the sludge outlets by mechanical apparatus. The Straight-line collector, or apparatus of a similar type, is used in rectangular and relatively narrow

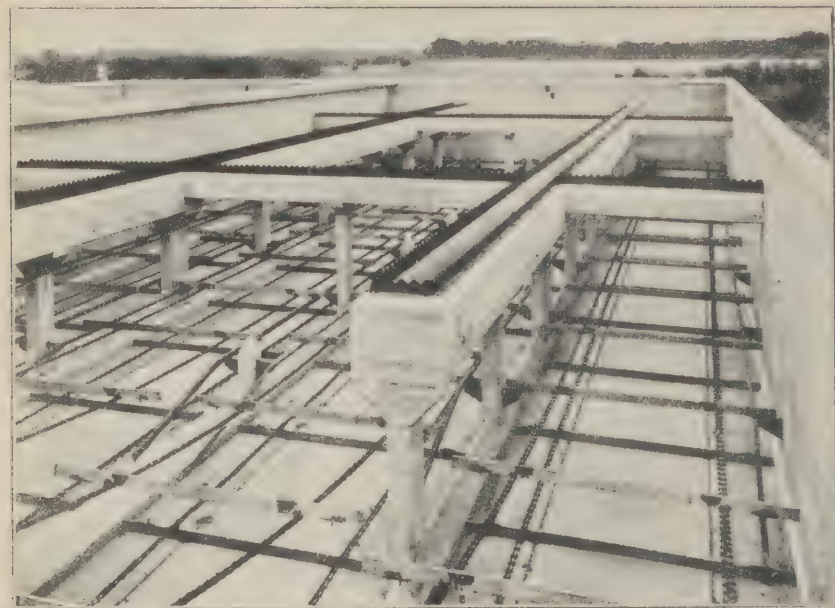


FIG. No. 161. Sludge collector in a rectangular tank. Scrapers or flights carry the sludge into the hopper at the end of the tank. (Courtesy of the Jeffrey Manufacturing Co., Columbus, Ohio).

FIG. No. 162. One type of clarifier and sludge collector used in circular tanks. (Courtesy of the Link-Belt Co., Philadelphia, Pa.).

tanks. The Straight-line collector consists of a series of collecting flights, or transverse, wooden or metal scrapers, the ends of which are attached to an endless chain on each side of the tank. The chains with their attached flights extend the entire length of the tank. The flights are pulled by the lower portion of the chain along the bottom of the tank from the outlet to the inlet end and are returned to the outlet end by the upper part of the chain. In their passage along the bottom of the tank, the flights collect and move the deposited solids to a hopper or sump in the floor of the tank at the inlet end. The upper flight may be installed so as to skim off and remove scum and grease (Fig. No. 161).

FIG. No. 163. Dorr clarifier showing superstructure and the shape of the tank. (Courtesy of the Dorr Manufacturing Company, New York, N. Y.).

The Dorr clarifier is designed to operate in square or circular tanks. It consists essentially of raking arms which are attached to a central column and a superimposed motor driven mechanism. The rakes or scrapers revolve slowly around the tank, passing over and sweeping the floor area and carrying the deposited solids to a central sump (Fig. No. 163).

The "Sifeed" clarifier is a recent development of the Dorr clarifier. The tank is circular and the influent is carried under the tank and passed into the tank through a central feed pipe and central column. The sewage flows radially and the effluent is discharged through outlets located at the periphery of the tank.

The sludge is removed from the sump or hopper of the sedimentation tank by gravity or by means of pumps. Where removal is by gravity, there should be four feet of initial head and

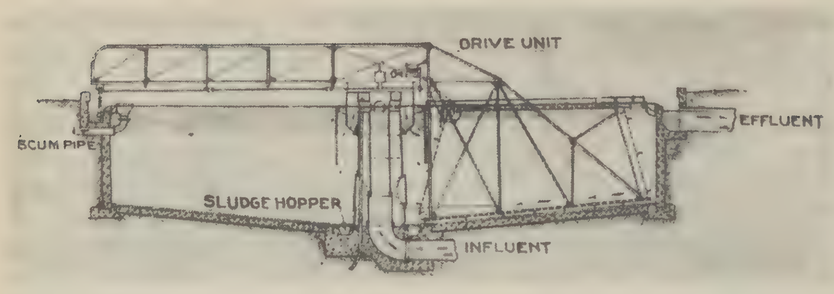


FIG. No. 164. Diagrammatic view of clarifier and sludge collector for round tanks. This is a Straight-line collector adapted to a round tank (Fig. No. 162). (Courtesy of the Link-Belt Co., Philadelphia, Pa.).

the pipes should have at least three per cent fall between the tanks. The withdrawal of sludge from the sedimentation tank is continuous, or periodical at intervals which vary with the operating conditions. Usually, the sludge is withdrawn from once to several times a day. Incomplete removal of the sludge or failure to withdraw the sludge at proper intervals will result in septic decomposition in the sedimentation tank, and consequent increase in the biochemical oxygen demand and decrease in the stability of the effluent.

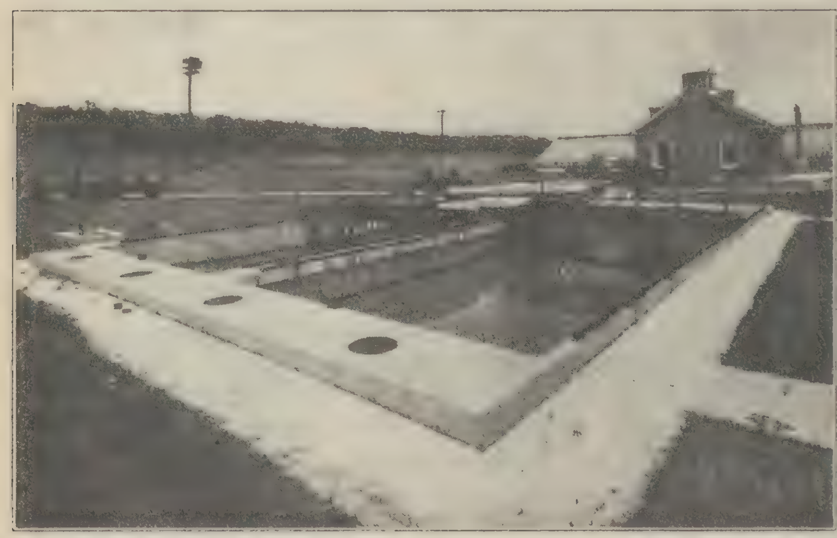


FIG. No. 165. Crane type clarifiers in longitudinal tanks. (Courtesy of the Hardinge Co., York, Pa.).

Plain sedimentation will remove from 40 to 75 per cent of the suspended matter, but the proportion removed depends upon a number of local factors and varies greatly among different plants. Usually, plain sedimentation will remove from 50 to 60 per cent of the suspended solids. The amount of sludge that can be removed from the sewage in a plain sedimentation tank will depend on the proportion of solids that settle out of the sewage and the moisture content of the sludge as it flows from the tank. Under average conditions, sludge containing approximately 98 per cent of moisture is deposited at the rate of about 10,000 to 12,000 gallons per million gallons of sewage. Under like conditions, sludge containing 95 per cent of moisture is removed from the sewage at the rate of about 3,000 gallons per million gallons of sewage.

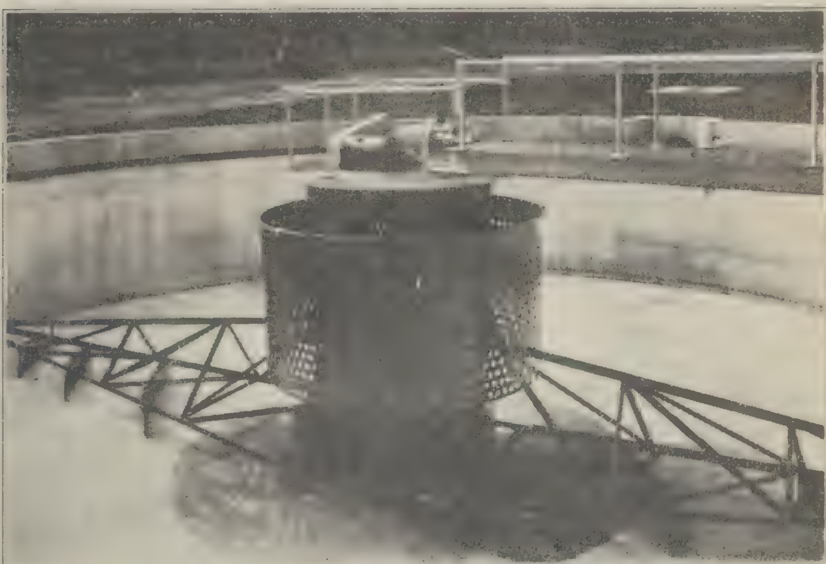


FIG. No. 166. Dorr "Sifeed" clarifier. The sewage flows into the tank through the central siphon. The effluent flows out at the periphery of the tank. (Courtesy of the Dorr Manufacturing Co., New York, N. Y.).

Sludge disposal. The disposal of the sludge removed from plain sedimentation tanks is discussed on pages 645 and 662.

Advantages and disadvantages of plain sedimentation. Plain sedimentation produces practically no disagreeable odors, provided anaerobic decomposition is prevented. The

FIG. No. 167. See Fig. No. 166. The "Sifeed" clarifier in operation. (Courtesy of the Dorr Manufacturing Co., New York, N. Y.).

effluent is relatively fresh and can be treated more effectively by filtration or dilution than the effluent from a septic tank (*infra*). However, the sludge is highly putrescible and must be subjected to further treatment before final disposal.

SEPTIC TANK TREATMENT

A septic tank provides for sedimentation and storage of suspended solids until anaerobic decomposition, or septic action, has effected a certain degree of stabilization and reduction in the volume of the retained organic material (Fig. No. 168). Any tank in which septic decomposition occurs is a septic tank, but the term *septic tank* is commonly applied only to the single story tank. While the septic process is utilized in the operation of the two story Imhoff tank, this tank is usually known as an *Imhoff tank*, rather than a septic tank.

The septic process. As the sewage enters the tank, the rate of flow is decreased to a point where a portion of the settleable solids will settle out as sludge on the bottom of the tank, while the floating material forms a scum on the surface. Anaerobic decomposition occurs in both the sludge and the scum, producing disintegration and liquefaction of the organic material with the formation of gases and reduction in volume of the solid constituents. As the gas is released from the sludge on the bottom of the tank, it carries the lighter particles of organic matter upwards into and through the overlying liquid to increase the thickness of the scum layer on the surface. Under certain conditions, the scum may form a hard compact

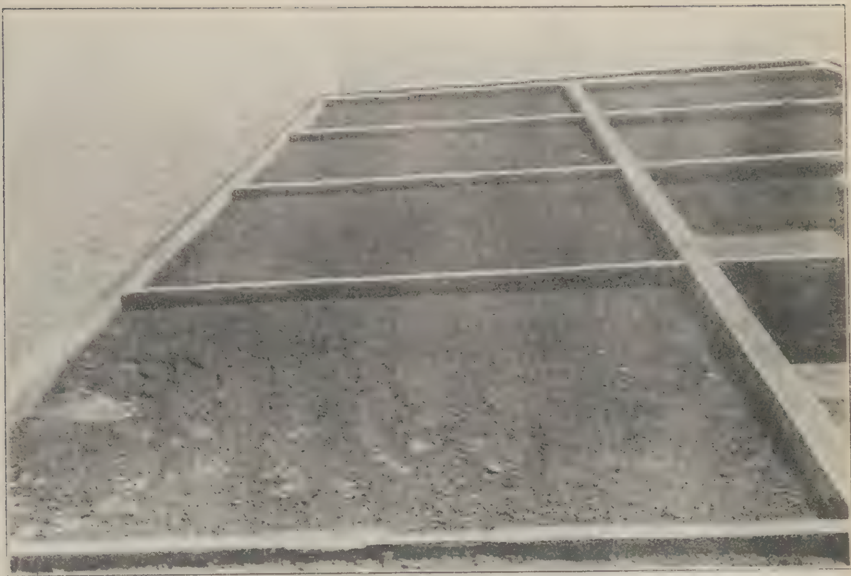


FIG. No. 168. Septic tank showing accumulation of scum on the surface.

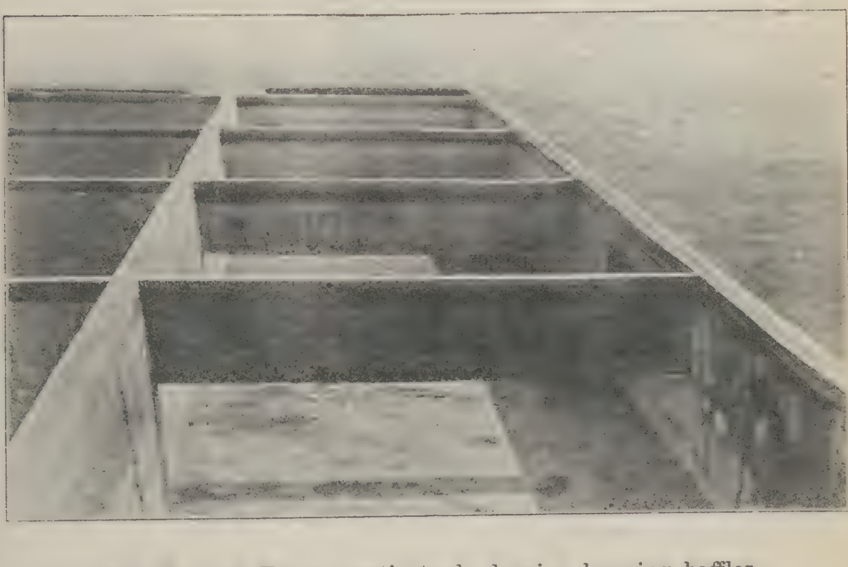


FIG. No. 169. Empty septic tank showing hanging baffles.

mass from a few inches to as much as two feet or more in depth.

A properly designed and operated septic tank will remove from 40 to 75 per cent of the suspended solids, the proportion varying with the strength of the raw sewage, the rate of flow and the length of the detention period. Under average conditions about 45 to 50 per cent of the suspended solids are removed.

The effluent as it leaves the tank is a foul, highly putrescible liquid containing little or no oxygen. It is still capable of producing nuisances and may contain pathogenic organisms. However, the removal of a considerable proportion of the suspended solids so modifies the character of the sewage that further stabilization can be more readily accomplished by dilution or by oxidation procedures involving the use of filters or contact beds.

The solids which are retained in the tank as sludge or scum continue to undergo anaerobic decomposition and, under suitable conditions, become stabilized to a degree which will permit of ultimate disposal without creating nuisances.

Design of septic tanks (Fig. No. 169). The ordinary septic tank is a rectangular concrete basin from 6 to 12 feet or more in depth. The length of the tank is governed by the amount of sewage to be treated and the length of the detention period. The width is usually 20 to 50 per cent of the length. Septic tanks are usually open, although they may be covered. There should be two or more tanks so that the plant can be operated while one tank is out of service for cleaning. Because of the disturbing effects of winds and the short circuiting currents which tend to form in the larger tanks, the septic process can be more easily controlled in relatively small tanks.

Inlets and outlets. The sewage is admitted to the tanks over a weir or through a pipe or pipes in such a way that the rate of flow is immediately decreased so as to obtain effective sedimentation and avoid disturbance of the scum or sludge.

Where a weir inlet is used, a scum board is placed from 2 to 6 inches in front of it. The scum board extends downward for at least 2 feet so that the flow of sewage is diverted to a point below the scum, the velocity of flow being effectively checked by the weir and the scum board.

Pipe inlets may discharge behind a scum board or they may be submerged to about mid-depth of the tank. Inlet pipes which curve downward and discharge below the scum layer may be used, especially in small tanks. The weir inlet is most commonly utilized.

The outlet may consist of a weir or of pipes which pass through the wall of the tank. In either case the outlet is protected by a scum board so that the sewage is drawn from the middle depth of the tank where the septic action is least pronounced. Usually, the tank effluent passes from the outlet into a concrete conduit which may receive sewage from other tanks and from which the sewage is drained to filters, contact beds or into an outlet pipe.

Baffles and scum boards (Fig. No. 169). Transverse baffles may be built into the tank to prevent the formation of currents. The baffles are usually hanging partitions which extend from the top to about mid-depth of the tank. Standing baffles may be installed and consist of partitions which extend upward from the bottom to about mid-depth of the tank. There may be one baffle located in front of the inlet, or there may be several at intervals throughout the length of the tank (Fig. No. 169). Proper baffling produces a uniform rate of flow through the tank, but too many baffles may increase the velocity to an extent which will create currents and eddies and interfere with sedimentation.

Scum boards are small transverse baffles which extend downward into the sewage for a distance of from a few inches to two feet or more and prevent movement of the scum. A scum board is usually placed immediately in front of the inlet and another behind the outlet. There may be other scum boards at intervals between the inlet and the outlet. Hanging baffles also serve as scum boards.

Bottoms of septic tanks. The bottom of the ordinary horizontal flow septic tank is level except for the slope necessary to facilitate the removal of the sludge. Where practicable, the sludge is removed from the tank by gravity to the sludge well or drying beds, and the location of the sludge outlet will influence the construction of the bottom of the tank. This outlet may be a sump in the center of the tank. In other instances, gutter drains in the floor carry the sludge to an outlet, or outlets, in the center, end, or side of the tank. The

slope of the bottom towards the sump or drain varies from two to eight per cent but must be such that the sludge can be readily removed. The tank may have a hopper bottom similar to the U. S. Army septic tank (*infra*).

The U. S. Army septic tank (Fig. No. 170). The essential feature of the U. S. Army septic tank is the hopper construction of the bottom which, with the baffles, serves to convert the tank into a series of compartments. The baffles tend to produce a vertical flow in and out of each compartment.

Each compartment is an independent unit for the storage and digestion of the sludge. The first compartment is the largest, in order to provide space for the greater quantity of solids that will settle out near the inlet.

Sludge pipes pass from the bottom of each compartment to the outside of the tank and are rendered independent of each other by valves. When the valve on the sludge pipe from any one of the compartments is opened, the hydrostatic pres-

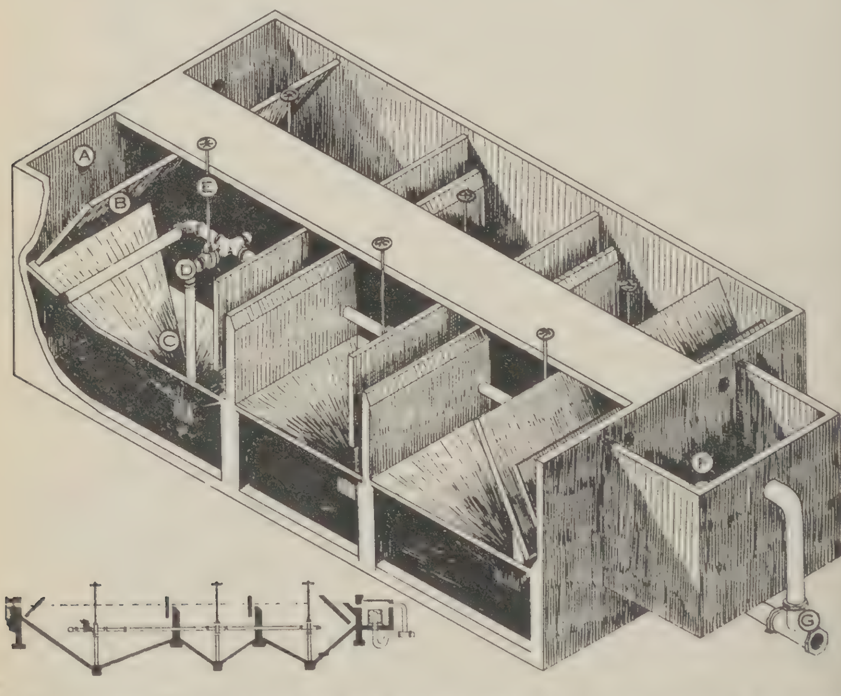


FIG. No. 170. U. S. Army Septic tank (Schematic). A—Inlets. B—Scum board and baffle. C—Hopper bottom. D—Sludge pipes. E—Sludge valve stem and wheel. F—Siphon chamber. G—Outlet.

sure exerted by the overlying fluid forces the sludge outward through the pipe. Thus, the sludge can be removed from any compartment without disturbing that in the other compartments and without removing the fluid from the tank.

Operation of septic tanks. In the operation of a septic tank, the sewage must remain in the tank long enough for a greater or less proportion of the settleable solids to fall below the level of the outlet. This detention period varies in different plants from one to twenty-four hours. The design rate of flow and detention period are usually based on the average daily rate of flow of sewage. As the flow of sewage to the tank varies from hour to hour and from day to day, the rate of flow through the tank and the length of the detention period are subject to hourly and daily variations. In some states, the state laws or regulations require that the capacity of a septic tank, and therefore the rate of flow and the detention period, be based on the estimated or actual average rate of flow of sewage during certain hours of the day, as for example, between 6 A.M. and 10 P.M. The length of the detention period and the rate of flow depend on the character of the sewage, the nature of the treatment to which the sewage will be subjected after passage through the tank, and the capacity of the tank in relation to the volume of sewage to be treated. Within a 24-hour period, a longer detention period will remove a larger quantity of solids than a shorter period. Further detention after 24 hours does not increase the efficiency of the tank sufficiently to justify the procedure, and may produce over-septicization of the effluent which will interfere with the action of filters or contact beds. In practice, the detention period varies from two to eight hours, and the rate of flow from less than 50 feet per hour to as much as 200 feet or more.

Care of tanks. A uniform distribution of sewage through the tank should be maintained by the proper adjustment of inlet valves or gates. The baffles, weirs, and other exposed surfaces of the tank should be kept free from scum and deposits. A dense, thick scum may form which will interfere with the escape of gases and cause the retention in the scum of a considerable quantity of decomposing material which would otherwise be deposited as sludge on the bottom of the tank. To prevent the development of such scum, it may be

necessary at times, especially during a period shortly after a clean tank has been placed in operation, to break up the scum with water under pressure from a hose or by mechanical means.

Odor control. Most of the complaints of nuisances produced by septic tanks are caused by odors due to gases generated in the decomposing organic material. Certain odors are perceptible only in the immediate vicinity of the plant and cannot be detected at relatively short distances away—fifty to one hundred yards. Other odors are persistent and will travel for comparatively long distances. The latter are due principally to hydrogen sulphide. The distance at which an odor can be detected is governed largely by atmospheric conditions and the velocity and direction of the air currents, but odors may cause nuisances at a distance of a mile or more from the plant.

The control or reduction of persistent and offensive odors is accomplished chiefly by cleanliness. All screenings should be properly disposed of and all exposed parts of the screen chamber, tanks and channels kept free from deposits of putrescible material. Prechlorination is an effective method of reducing odors (page 700). Frequently, beautifying the surroundings of a sewage disposal plant with paint, shrubbery, grass, and flowers will produce a psychological effect which will cause a marked decrease in complaints of odors. The appearance of a bare, unkempt, unpainted plant causes many persons to expect and anticipate the production of offensive odors and to magnify the effect of those odors which are produced.

Sludge removal. Septic tank sludge is composed of the disintegrated and partially decomposed solids which have been deposited in the bottom of the tank. It contains from 90 to 95 per cent of water. Septic tank sludge is a dark tar-like substance, which, unless it has been subjected to a long period of detention in the tank, is putrescible and tends to produce offensive odors after removal from the tank.

The sludge should be allowed to remain in a septic tank as long as it does not interfere with the operation of the tank. Normally, about 70 cubic feet of sludge will be produced by each one million gallons of sewage passed through the tank. Ordinarily, septic tanks are so constructed that about 25 per cent of the capacity of the tank may be occupied by sludge without increasing the velocity of the flow to a degree which will prevent

proper deposition of solids. Usually, if as much as one-third of the tank is filled with sludge, a considerable proportion of the suspended material, which would otherwise be deposited as sludge, will pass out of the tank in the effluent. The tank should be cleaned whenever the amount of sludge, by decreasing the capacity of the tank, causes such an increase in the velocity of the flow that effective sedimentation of settleable solids is prevented. Usually the sludge must be removed from a septic tank every four to six months, although the time may vary from three months to a year.

The depth of the sludge in a tank can be roughly determined by measuring the depth of the overlying fluid and subtracting the figure thus obtained from the depth of the tank. The procedures described on page 644 may be used.

Methods of sludge removal. A flat bottomed tank must be dewatered before the sludge can be removed. This is done by first closing the inlet valves and then removing the supernatant liquid through drains designed for this purpose, or by pumps. The sludge is then moved towards and into the drainage sumps or gutters by squeegees or by water under pressure from a fire hose. From the drainage sumps the sludge flows by gravity or is pumped through the sludge drains to sludge beds or other places of disposal. When the tank is dewatered, the scum settles down onto and is removed with the sludge.

In the case of tanks with hopper bottoms, such as the U. S. Army septic tank (Fig. No. 170), it is not necessary to dewater the tank, as the sludge is forced through the sludge pipes by the hydrostatic pressure of the overlying fluid. In tanks of this kind the scum is removed by breaking it up so that it will settle down and be converted into sludge.

IMHOFF TANK TREATMENT

The Imhoff tank (Fig. No. 171) is a two story tank consisting of an upper sedimentation or flow chamber and a lower chamber in which the sludge is stored and digested. The flow chamber is connected with the sludge chamber below by a narrow slot which permits the downward passage of the settleable solids, but which is so trapped that the gases generated in the sludge are diverted into gas vents and do not pass upward into the sewage in the flow chamber.

Imhoff tank treatment consists, therefore, of two separate processes. The solids that settle out in the flow chamber are removed from the sewage by plain sedimentation, while the sludge retained in the sludge chamber undergoes anaerobic decomposition. As the sewage does not come in contact with the septic sludge, the effluent has a comparatively low biochemical oxygen demand and can be much more easily and effectively disposed of by secondary treatment or dilution than the effluent from a septic tank.

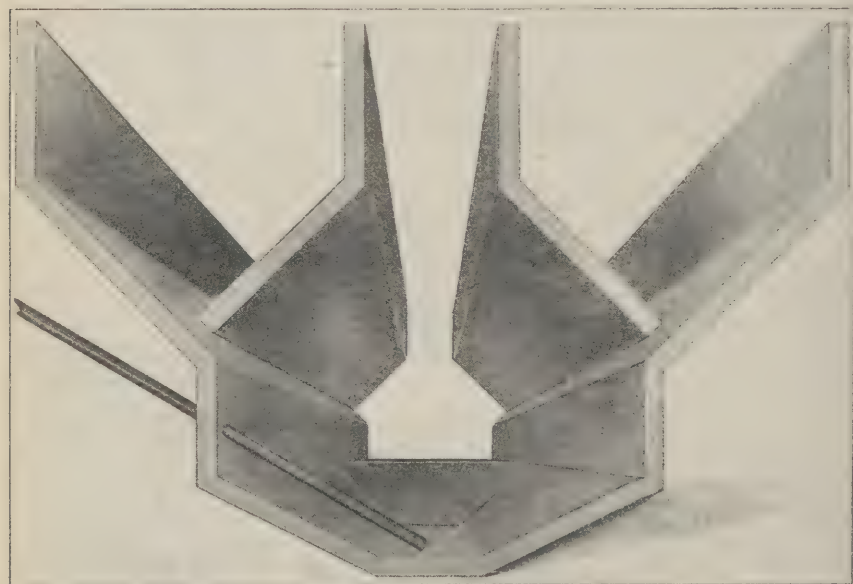


FIG. No. 171. Schematic representation of Imhoff tank, showing flow chambers, slots, gas vent between flow chambers, sludge chamber and sludge pipe.

The deposits resulting from the plain sedimentation in the flow chamber are immediately and continuously removed by dropping through the slot into the sludge chamber. The sludge in the sludge chamber of an Imhoff tank is digested in the same manner as the sludge in a septic tank, but in an Imhoff tank the sludge is retained for a sufficient length of time to permit thorough decomposition and stabilization. The sludge formed by Imhoff tank treatment is, ordinarily, much less putrescible than that obtained from septic tanks and can usually be disposed of by drying with the creation of but comparatively little nuisance.

The gas bubbles which pass from the sludge chamber up through the gas vents carry finely divided suspended solids which form a scum on the surface of the liquid in the vents. As no gas enters the flow chamber, no scum is formed in the flow chamber, except that due to light, floating material.

FIG. No. 172. Empty Imhoff tank showing gas vents and flow chamber. (Courtesy of the Pennsylvania Department of Health, Harrisburg, Pa.).

Design of Imhoff tanks. The Imhoff tank may be either the horizontal (*parallel*) flow or the radial flow type, but the principles involved are the same in both types. The horizontal flow type is the most common (Fig. No. 172).

The horizontal flow tank. The horizontal flow tank is rectangular in shape. Its capacity, as determined by the length and width, is governed by the length of the sewage detention period, the character and the quantity of the sewage to be treated, and the proportion of tank utilized for gas vents. The ratio of the width to the length varies greatly in different installations, the length of some tanks being only twice the width, while in others the length is ten or more times the width. The average ratio of length to width is about three or four to one.

As it is necessary in the operation of an Imhoff tank to store relatively large quantities of sludge over a considerable period of time, the Imhoff tank is much deeper than a plain sedimen-

tation or a septic tank. The total depth of Imhoff tanks varies from 20 feet to as much as 35 feet. Most tanks have two feet of freeboard above the level of the sewage.

The flow chamber. The flow chamber is a trough-like compartment through which the sewage flows and in which sedimentation occurs. The bottom of the flow chamber is V-shaped and terminates in a slot from 6 to 8 inches in width, through which the solids drop into the sludge chamber. The slot is trapped so

FIG. No. 173. Small horizontal flow Imhoff tank. The influent channel is on the left. The steel oil drum in the center is used in applying lime solution to the sludge through the gas vent for the purpose of preventing foaming (page 642).

as to divert the gases rising from the sludge into the gas vents. The trap is usually formed by an 8 to 12-inch horizontal overlap of the lower edges of the bottom of the flow chamber. In some instances, the trap may be formed by a beam placed just below the slot or by a projection from the side of the tank.

The flow chamber usually extends the length of the tank. The depth of the flow chamber varies somewhat with the total depth of the tank, but is usually between 10 and 16 feet from the top of the chamber to the slot.

In order to minimize the retention of solids in the flow chamber, the sides of the V-shaped bottom should have a slope of at least 45 degrees and should have hard, smooth surfaces. If solids are retained on the sloping sides of the bottom, they will decompose and convert the flow chamber into a septic tank which will, to that extent, defeat the purpose of the Imhoff tank treat-

ment through contamination of the effluent with the products of septic decomposition.

The sludge chamber. The sludge chamber forms the lower part of the tank and receives the solids from the flow chamber above. The length of the sludge chamber usually corresponds to the length of the tank as a whole, and the width and depth are determined by the quantity of sludge to be stored and the length of the sludge detention period. The depth is usually between 10 and 15 feet, while the width may or may not be as great as that of the upper part of the tank.

The sludge chamber should provide storage space for all the sludge produced during a period of from six to nine months, particularly if the difficulties encountered in the disposal of sludge during cold weather render it necessary to store the sludge in the tank during the winter months. Under average conditions, storage for a period of six months will require approximately two cubic feet of space for each person served.

The bottom of the sludge chamber is usually hopper shaped or divided into a series of hoppers in order to facilitate the removal of the sludge. The floor of each hopper should have a minimum slope of one on two. A sludge pipe, usually about eight inches in diameter, passes from near the bottom of the hopper upward and out through the side of the tank so that the upper portion is at least four to six feet below the level of the surface of the sewage in the flow chamber. Water pipes may be installed in the sludge chamber, usually around the hopper or the mouth of the sludge pipe. These pipes serve to admit fresh water which is at times required to modify the bacterial action, to agitate the sludge and release the entrained gas, or to facilitate the removal of the sludge.

Gas vents. The gas vent is a chamber extending from the sludge chamber upward beside the flow chamber or chambers to the top of the tank (Fig. No. 171). The length of the gas vent may correspond to that of the flow chamber or there may be a vent above each of the several hoppers in the sludge chamber. The surface area of the gas vent is usually from 15 to 25 per cent of that of the tank. In any event, the gas vents should be wide enough to afford entrance to the sludge chamber when the tank is empty. In tanks having only one flow chamber, there is usually a gas vent chamber on either side of the flow chamber.

Where two flow chambers are employed, the gas vent is ordinarily placed between the flow chambers.

Inlets and outlets. The sewage is usually admitted to the flow chamber from a conduit through sluice gates or over weirs, usually the latter. The velocity in the inlet and outlet channels should be sufficient to prevent sedimentation of solids in the channels. The inlets should be so constructed that the depth of sewage in the tanks remains constant within narrow limits. Otherwise, diffusion between the liquids in the flow chamber and the sludge chamber will occur. The inlets and outlets should be arranged to permit reversal of the flow (page 642).

Scum boards and baffles. Scum boards should be placed immediately behind the outlet weirs to retain floating solid material. Baffles are not ordinarily installed in Imhoff tanks because they would tend to produce vertical currents and thus interfere with the passage of solids through the slot into the sludge chamber.

Radial flow tanks. The radial flow tank differs from the parallel flow type in that it is circular in shape and the sewage flows radially from a central inlet. The functions of the flow and sludge chambers are the same as in the horizontal flow tanks.

Operation of Imhoff tanks. When a new or a clean tank is placed in service, some time elapses before the bacterial activity in the sludge is sufficient to produce thorough digestion. The length of this period varies from two to three weeks to two months or longer, depending on the atmospheric temperature and the character of the sewage. In some instances a period of six months is necessary to develop a thoroughly ripened sludge. A shorter time is required in warm weather than in cold. The ripening of the sludge in a clean tank may be hastened by seeding with digested sludge from a tank in operation, or by the agitation of the sludge with fresh water admitted through water lines to the sludge chamber.

The sludge must have an alkaline reaction if proper digestion is to be obtained. An acid reaction produces a light colored, foul smelling sludge which is difficult to dry and may cause foaming (*infra*). Acid decomposition may occur in tanks that are started at a time when cold weather will delay ripening for a considerable period of time. The addition of lime to the sewage may correct this condition or the tank may be filled with hard water before the sewage is admitted. In

some plants a constant pH reaction of between 7.2 and 7.6 is maintained in the sludge by the routine application of lime (Fig. No. 173).

Recently, activated carbon has been found to be more effective than lime in maintaining the proper pH reaction. It also promotes the digestion of the solids and tends to prevent foaming. The minimum amount used at one application is about two pounds of activated carbon per one thousand gallons of sludge (page 318).

Sewage detention period. The average detention period in the flow chamber is from one to three hours, usually about two hours. Longer detention will increase but little the quantity of solids removed, and may unfavorably modify the character of the effluent by permitting septic decomposition. The rate of flow varies from 50 to 150 feet per hour, the average being about 100 feet per hour.

Diffusion between chambers. The efficient operation of an Imhoff tank requires that there be a minimum of diffusion between the liquids in the sludge and flow chambers. The liquid in the sludge chamber should remain quiescent and any circulation of fluid through the slot will carry products of anaerobic decomposition from the sludge chamber into the effluent or will interfere with sedimentation. Sudden fluctuations in the level of the sewage in the flow chamber tend to cause currents which carry septic liquid from the sludge chamber upwards through the slot. Diffusion between the chambers may also be caused by rapid fluctuations in the velocity of the sewage flowing through the tank.

Where the tank has two flow chambers, any difference in the velocity or level of the sewage in the two chambers will cause diffusion between the sludge chamber and one or both of the flow chambers.

The chambers should be so connected and the inlets so constructed that the level of the sewage and the velocity of the flow are the same in both chambers. While changes in temperature or an increase in the quantity of sludge in the sludge chamber will result in a small amount of the liquid contents of the sludge chamber passing into the flow chamber, extensive diffusion can be prevented by designing and operating the tank so that changes in the level of the sewage in the flow chamber or chambers or variations in the rate of flow will be gradual.

As in the case of septic tanks, the design rate of flow and the length of the detention period are based on the average daily rate of flow of sewage, and are subject to hourly and daily variations.

Foaming. The ebullition of gas in the sludge may be sufficiently violent to force relatively large quantities of solid material up into the gas vents. This condition is called foaming, and excessive foaming may cause the liquid in the gas vents to overflow into the flow chambers. Foaming may also interfere with the digestion and removal of the sludge. A number of procedures have been employed for the control or prevention of foaming. The particular method, or combination of methods most applicable in a given situation must usually be determined by experimentation. The procedures most commonly utilized include the removal of a part of the sludge, the adjustment of the pH reaction of an acid sludge with lime, or by the addition of activated carbon, chlorination of the tank influent, agitation of the sludge by means of jets of fresh water from water pipes in the sludge chamber and the application of water under pressure to the surface of the liquid in the gas vents. The lime is applied directly through the gas vents. The chlorine should be added to the sewage either before or as it enters the tank. The amount of chlorine required to prevent foaming should be determined by experimental study.

Scum removal. The scum on the surface of the liquid in the gas vents may become dense enough to interfere with the escape of gas. It should be broken up at frequent intervals and the heavier portions allowed to sink into the sludge chamber. A pole, or water under pressure from a hose, can be used for this purpose. Grease and particles of floating material which pass through the screens will form a light scum on the surface of the sewage in the flow chamber. This scum should be skimmed off and thrown into the gas vents or disposed of by burial or burning before it undergoes decomposition. Usually it must be removed daily.

Reversal of flow. In the operation of an Imhoff tank, it is essential that there be a uniform distribution of sludge in the sludge chamber in order that the storage capacity of the chamber may be fully utilized. If there is a uniform velocity of flow through the flow chamber, the larger proportion of the solids will settle near the inlet end, with the result that the inlet end

of the sludge chamber is filled before any considerable quantity of sludge accumulates elsewhere in the chamber. In order to obtain a uniform distribution of the sludge, tanks should be so constructed that the flow through the flow chamber can be reversed at intervals and thus obviate the disproportionate accumulation of sludge at any one point in the sludge chamber. The flow is usually reversed at intervals of from one to two weeks.

Care of the flow chamber. If putrescible solids are deposited and retained within the flow chamber, they will decompose and impair the freshness of the effluent. All surfaces of the flow chamber, including weirs, scum boards, the sides of the tank, and particularly the sides of the V-shaped bottom, should be cleaned at frequent intervals. The material which accumulates on the sides of the bottom is pushed down towards or into the slot by means of long handled squeegees.

Sludge removal. The production of a well digested sludge which can be disposed of with minimum nuisance is an important objective of Imhoff tank treatment, and the removal of sludge at the proper time and in proper amounts is, therefore, an essential factor in the efficient operation of an Imhoff tank.

Ripe Imhoff tank sludge is characterized by a black or dark color, an inoffensive tar-like odor, and a granular or frothy appearance. It contains large quantities of entrained gases and has a moisture content of about 90 per cent. Imhoff tank sludge differs from septic tank sludge in that it contains less water and a larger quantity of gas, is granular rather than sticky or paste-like, and does not produce offensive odors. It dries to a spadeable condition in less time than septic tank sludge because the relatively larger quantity of entrained gas separates the particles of solid material and facilitates the drainage of the water.

Usually the sludge is removed by opening the valve on the sludge pipe (Fig. No. 171) and permitting the sludge to flow through the pipe under pressure exerted by the overlying fluid. Pumps may be employed to remove the sludge where the tanks are located or constructed so that hydrostatic pressure cannot be utilized.

After decomposition is well established, the ripe sludge should be removed in small quantities at frequent intervals, usually every two to six weeks if the disposal facilities permit. If all the sludge is removed, the difficulties incident to obtaining thorough digestion in a clean tank must be again overcome. Al-

so, the withdrawal of a large quantity of sludge at one time will disturb the hydraulic conditions in the tank and will probably result in the removal of some of the fresher and, therefore, more offensive material.

During the winter months, when it is difficult to dry the sludge it may be necessary to allow it to accumulate in the tank. However, sludge should be removed if the surface of the sludge deposit approaches to within 18 inches of the slot. If there is less than 18 inches of free space below the slot, the currents resulting from the production of gas in the sludge may carry decomposing solids through the slot into the effluent.

The depth of the sludge in the sludge chamber is roughly determined by measuring the depth of the overlying liquid and subtracting the figure thus obtained from the total depth of the tank below the flow line. The depth of the liquid may be determined by one of several methods. A flat weight consisting of a weighted board or metal plate a foot or more in diameter is attached to a graduated line of cord, wire or light chain and lowered through the sewage in the gas vent until its descent is checked by the upper surface of the sludge. The length of the submerged portion of the line represents the depth of the sewage above the sludge. The weight may be attached transversely to a graduated pole or iron rod instead of a line.

A suction pump with a weighted rubber suction hose may be used to determine the sludge level. The hose is lowered through the sewage while the pump is being operated and the length of the submerged portion of the hose at the point where sludge is first pumped represents the depth of the overlying sewage. The hose should be graduated in divisions of one foot. The suction hose may be lowered either through the gas vent or through the slot in the bottom of the flow chamber.

The sludge passes through the sludge pipe directly to the drying beds or other place of disposal, or to a sludge well from which it is distributed to drying beds by gravity or by pumping.

Odor control. Odor control at an Imhoff tank installation is accomplished by proper operation and cleanliness. The general measures to be employed are the same as those described for septic tanks (page 634). Prechlorination is a valuable measure for the control of odors (page 700). The procedures which prevent foaming and promote proper sludge digestion also

serve to control odor production (*supra*). Collection of the gas will decrease the odors disseminated by an Imhoff tank (*infra*).

Gas collection (page 648). Imhoff tanks can be equipped with apparatus for collecting and storing the gas generated in the sludge. The gas may be utilized for heating or power purposes, and gas collection is a practicable procedure from an economic point of view only when the gas can be used as a source of heat or power. Gas collection also serves to reduce odors due to gas, and gas may be collected and burned solely as an odor control procedure.

SEPARATE SLUDGE-DIGESTION

There has been a considerable increase in the use of the separate sludge-digestion procedures during recent years, and the development of mechanical apparatus for moving and handling the sludge has served to make this method of treating sewage more practical and efficient.

The separate sludge-digestion treatment has developed from and is in fact a modification of the two-story tank method of treating sewage. Instead of the sludge chamber, or digestion tank, being below and connected with the settling chamber, as it is in the Imhoff tank (page 637), it is completely separate from and may be at some distance away from the settling unit. The digestion of the sludge in separate tanks eliminates some of the operating difficulties inherent in the Imhoff tank treatment. Also, at times, the character of the terrain and other local conditions are such that the cost of constructing separate tanks is less than that of a two-story tank.

Separate sludge-digestion tanks are used for the digestion of sludge from plain sedimentation tanks, activated sludge and sludge produced by chemical precipitation. The basic features of separate sludge-digestion are the transfer of fresh sludge to a separate tank and the retention of the sludge until anaerobic decomposition takes place.

The digestion tank, or tanks, may be located immediately adjacent to or at a varying distance from the settling tanks, depending upon local conditions, such as the topography of the ground, the character of the subsoil, or the level of the ground water table.

FIG. No. 174. Sludge digestion tanks with floating covers. (Courtesy of the Pacific Flush-Tank Co., Chicago, Ill.).

The sludge may be completely digested in one tank or it may be partially digested in a primary tank and then transferred to a secondary tank. In some plants the primary tank is heated (*infra*) and the secondary is not heated. Usually, where primary and secondary tanks are used, the primary tank is smaller than the secondary tank, and the gas is collected from the former but not from the latter.

Types and design. Digestion tanks vary greatly in shape and design. They may be circular, rectangular or square and range from ten to forty feet in depth. The design of the bottom of a tank is determined largely by the method of removing the digested sludge. Where mechanical equipment is employed for this purpose, the tank is commonly circular in shape and has a comparatively flat bottom. Where the sludge is removed by gravity, the bottom is hopper shaped with slopes of one to three or greater.

Usually, the roof of a digestion tank is fixed, but some tanks are equipped with floating covers which serve to submerge and to reduce the quantity of scum, and to collect and hold the gas under uniform pressure. The floating cover lies on top of the liquid contents of the tank. The fixed roofs are ordinarily higher in the center, or domed, to provide space for the gas to collect.

Capacity. The total minimum capacity of the digestion tanks required in a given instance is, within limits, determined by several factors, among which are the character of the sewage

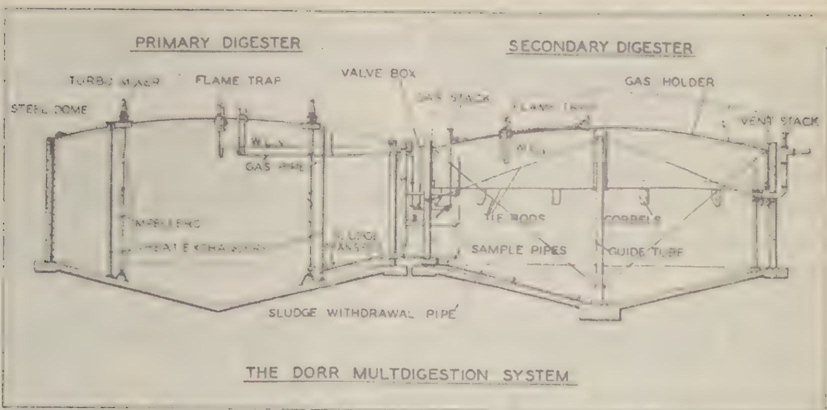


FIG. No. 175. A Dorr multidigestion system. Section of primary digester and secondary digester. (Courtesy of the Dorr Manufacturing Co., New York, N. Y.).

with regard to suspended matter content, the water content of the sludge, whether or not the tanks are heated (*infra*) and the temperature maintained, and the intervals at which digested sludge is withdrawn. Depending upon the presence or absence of any of these factors, the required capacity varies from one to four cubic feet per capita. The larger capacity is required for unheated tanks.

Operation of separate sludge-digestion tanks. In some plants the digestion tanks are equipped with mechanical apparatus for breaking up the scum, distributing the raw sludge throughout the tank, and moving the digested sludge to the sludge outlets. Usually, the scum breaker consists of slowly revolving arms which by means of dragging chains or other devices serve to break up or to prevent the formation of scum. The digested and compacted sludge is moved towards a central outlet by scrapers or plows placed just above the floor of the tank.

Heating of the sludge. Heating the sludge promotes rapid anaerobic decomposition and more thorough digestion. The main advantages gained by heating the sludge are that digestion proceeds at a uniform rate irrespective of climatic conditions, and many of the difficulties attending the digestion of sludge in a two-story tank are avoided (page 640).

A digestion tank is usually heated by hot water coils within the tank. The temperature ranges from 70°F. to 90°F., but is usually maintained between 80°F. and 85°F. Digestion is delayed

at low temperatures, and high temperatures of the circulating water tend to cause crusting of the sludge on the outside surface of the pipes.

Collection and utilization of the gas. The gas collects in the upper portion of the tank, under a dome shaped roof, or a floating cover. It may be piped from the digestion tank to another tank, known as a gas holder, or directly to a gas furnace or engine. The gas may be used to heat the sludge or to operate gas engines.

The gas consists principally of methane, but also contains hydrogen sulphide, carbon dioxide, and other gases. The latter must be removed in order to avoid corrosion of the piping carrying the gas. A flame trap is necessary to obviate danger of an explosion (Fig. No. 175).

Control of digestion. When a new or a clean tank is placed in operation, digestion of the raw sludge is started by seeding ripe sludge from another tank. The sludge undergoing digestion should have a pH of about 7.4. Raw sludge is acid and digested sludge is usually, but not always, alkaline. Consequently, if the raw sludge is added in quantities which are small in relation to the quantity of sludge in the tank, the proper pH is maintained. If too much raw sludge is added at one time the pH value is lowered and digestion is retarded. Acidity of sludge may be corrected and the optimum pH value restored by the addition of lime or activated carbon. These should be applied in small quantities at frequent intervals, rather than in large doses, but large doses may be needed to control foaming tanks (page 642). Considerable time, possibly a number of months or a year or more, may be required to adjust conditions in a digestion tank so that the highest degree of efficiency is obtained. Heating the sludge tends to promote digestion during this period and thus reduces the time required to start a tank.

Well digested sludge is similar in character to that produced by a properly operated Imhoff tank (page 643).

The digested sludge is usually removed from the tank by gravity. The sludge should be drawn in small quantities at intervals of from 2 to 4 weeks.

As digestion proceeds the sludge becomes more compact and settles in the lower part of the tank leaving a zone of relatively clear liquid. This liquid is septic and should not be passed directly into the diluting water. It may be discharged back into the

sedimentation tank, or into the sewage flowing into the plant. If discharged into the sedimentation tank or into the incoming sewage, strong liquor from a digestion tank impairs the effluent and makes it more septic. If at all practicable, the liquid from a digestion tank should be treated separately. In some instances it is passed through sand filters.

Efficiency of separate sludge-digestion. The digestion of the sludge in a separate and independent tank increases flexibility in the operation of the plant.

Usually, the cost of constructing plain sedimentation tanks and separate sludge-digestion tanks is less than that of Imhoff tanks.

Where the digestion tanks are covered and the gas is collected and burned, a separate sludge-digestion plant produces much less objectionable odor than a septic tank or an Imhoff tank installation.

Under good operating conditions the separate sludge-digestion tank produces a sludge that will dry readily, is easily handled and is relatively inoffensive.

CHEMICAL PRECIPITATION

(*Coagulation*)

Sewage may be treated by the addition of chemicals which cause coagulation, with subsequent precipitation of the suspended and dissolved solids, including colloidal matter. Chemical precipitation, as a method of treating sewage, has not been utilized to any considerable extent in actual practice. It has, however, during recent years, been the subject of much study and experimental work, particularly in the treatment of sewage containing industrial wastes.

Iron salts, aluminum sulphate (alum), chlorine and lime are most commonly used in the coagulation of sewage. The iron salts that have been found to give good results are ferric sulphate, ferric chloride, ferrous sulphate (copperas) and chlorinated copperas (ferrous sulphate and chlorine). Lime is added to produce the proper alkaline reaction and assist in converting the partly soluble ferrous hydroxide into insoluble ferric hydroxide. Generally, chlorine must also be added to produce a good floc.

Aluminum sulphate (alum) is an efficient coagulant in the treatment of sewage. As it is effective in the pH ranges usually

found in sewage, no lime or other chemicals are necessary to produce the desired reaction. Alum can be applied by means of an ordinary dry chemical feeder (page 272). Usually about four grains per gallon, or approximately 575 pounds per million gallons, will produce a clear effluent. The dosage of alum need not be strictly accurate, as good results will be obtained even though the quantity added to the sewage is considerably smaller or greater than the optimum. On the other hand, the amount of iron salts applied must be carefully controlled in order to prevent excessive turbidity of the effluent.

A number of different chemical precipitation processes have been developed experimentally. Generally, the methods used to coagulate sewage are the same in principle as those employed in the coagulation of water (page 243). The coagulant must be thoroughly mixed with the sewage. Flocculation or violent mixing is usually necessary where iron salts are used as coagulants, and is desirable, though not necessary, if alum is used.

FIG. No. 176. Flocculator for insuring thorough mixing of chemicals with sewage. (Courtesy of the Dorr Manufacturing Co., New York, N. Y.).

In many instances, a special mechanism known as a flocculator is used for mixing the coagulant and the sewage (Fig. No. 176).

Under proper conditions and where the chemical precipitation is carried far enough, practically all the suspended solids are removed and the effluent is clear and sparkling. However, as the biochemical oxygen demand has been reduced only 60 to 80 per cent, the effluent is not yet stable.

The sludge produced by chemical precipitation is somewhat more voluminous than that resulting from plain sedimentation. Otherwise, it has the same characteristics as the sludge from plain sedimentation tanks (page 627).

Coagulation with chemicals is most generally practiced in the operation of separate sludge-digestion plants (page 645). This method can be used with Imhoff tanks, and will produce a clearer effluent.

THE ACTIVATED SLUDGE PROCESS

The activated sludge method of sewage treatment is a biological process by which the raw sewage is intimately mixed with biologically active sludge, known as *activated sludge,* under conditions which produce flocculent coagulation of the suspended and dissolved solids and the colloidal matter, and consequent clarification of the sewage.

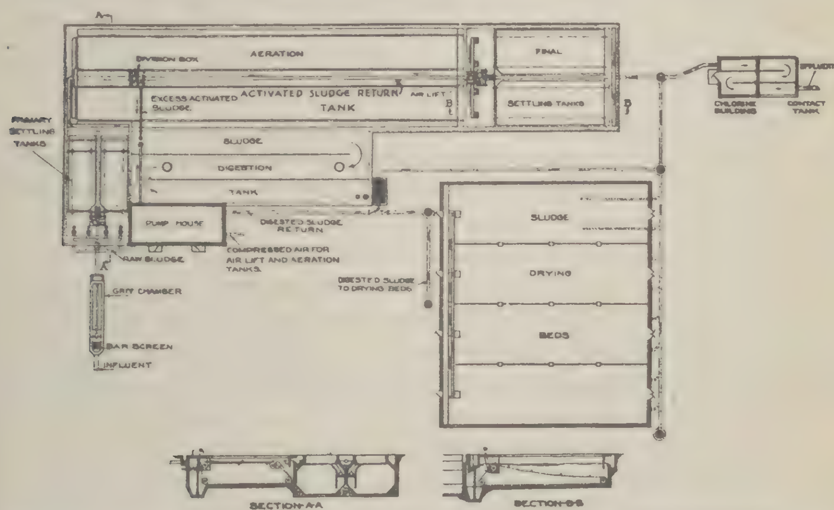


FIG. No. 177. Diagram of an activated sludge plant showing various features. (Courtesy of the Link-Belt Co., Philadelphia, Pa.).

Several theories exist as to how activated sludge produces coagulation, and the process is not well understood. It seems that it is partly physical and partly physicochemical and biological in nature. The flocs of the activated sludge contain vast numbers of aerobic and facultative organisms. Theoretically, these organisms consume the finely divided organic matter and thus increase the capacity of the flocs to absorb the colloidal matter, which is in turn consumed by the organisms. This process is called activation and the product is activated sludge. When activated sludge is intimately mixed with fresh sewage in the presence of air it will cause coagulation of the suspended, dissolved and colloidal matter contained therein and the activation of the fresh coagula by inoculation with aerobic organisms.

The fresh sewage is clarified by adding a predetermined amount of activated sludge and passing the sewage containing the activated sludge through an aeration tank in which it is thoroughly and continuously agitated by air pressure or by mechanical means (Fig. No. 179). The introduction of diffused air under pressure into the flowing sewage serves to keep the activated sludge in suspension and bring it into contact with all of the suspended and colloidal matter in the sewage and, at the same time, to maintain strict aerobic conditions. Similar results are accomplished by stirring the sewage with mechanical devices which bring successive portions of the sewage into contact with the atmosphere from which the required oxygen is absorbed. The sewage flows from the aeration tank into a settling tank where the coagulated solids are removed by plain sedimentation.

The flocculent masses of coagulated material, in their passage through the sewage, collect and entrap the finely divided suspended solids, bacteria and colloids and, in effect, filter the sewage by passing the filter material through the sewage, rather than the sewage through a filter. This process will remove 90 to 95 per cent of the suspended solids and produce an effluent which can be disposed of without further treatment, in so far as the creation of a nuisance is concerned. The effluent may, however, still contain pathogenic bacteria which must be destroyed, if their elimination is necessary, by disinfection (page 699).

The organic matter during its passage through the aeration and sedimentation tanks is being continuously digested, oxidized and, to some extent, nitrified by the aerobic bacteria. The sludge which settles out in the sedimentation tanks is a thin, mud-like,

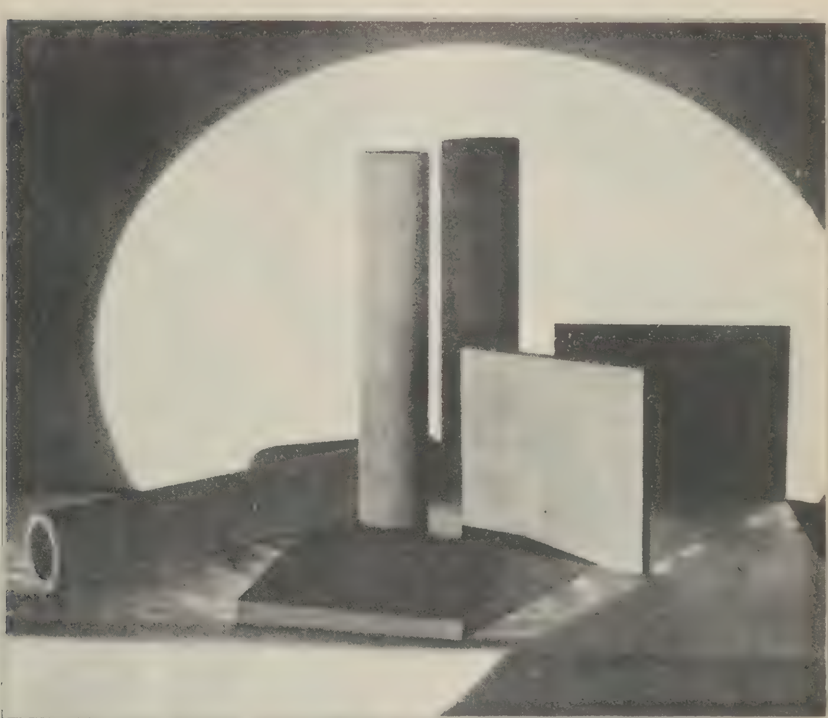


FIG. No. 178. Porous plates and tubes for the diffusion of air in aeration tanks. (Courtesy of the Norton Co., Worcester, Massachusetts).

golden brown, flocculent mass containing from 97.5 to 99 per cent of moisture, the average being about 98 per cent. The sludge contains a larger proportion of nitrogen and has a greater fertilizing value than that produced by any other form of tank treatment.

Fig. No. 177 shows, diagrammatically, the layout of a small activated sludge plant.

Preliminary clarification. Usually, some form of preliminary treatment is employed to remove a greater or less quantity of the suspended solids before the sewage passes to the aeration tank. Grit and similar heavy solids should be removed from the sewage prior to aeration, as they tend to settle out in the aeration tank and to hold the sludge on the bottom of the tank. Oil and other greasy trade wastes interfere with the flocculation in the aeration tank and should be removed by preliminary treatment measures.

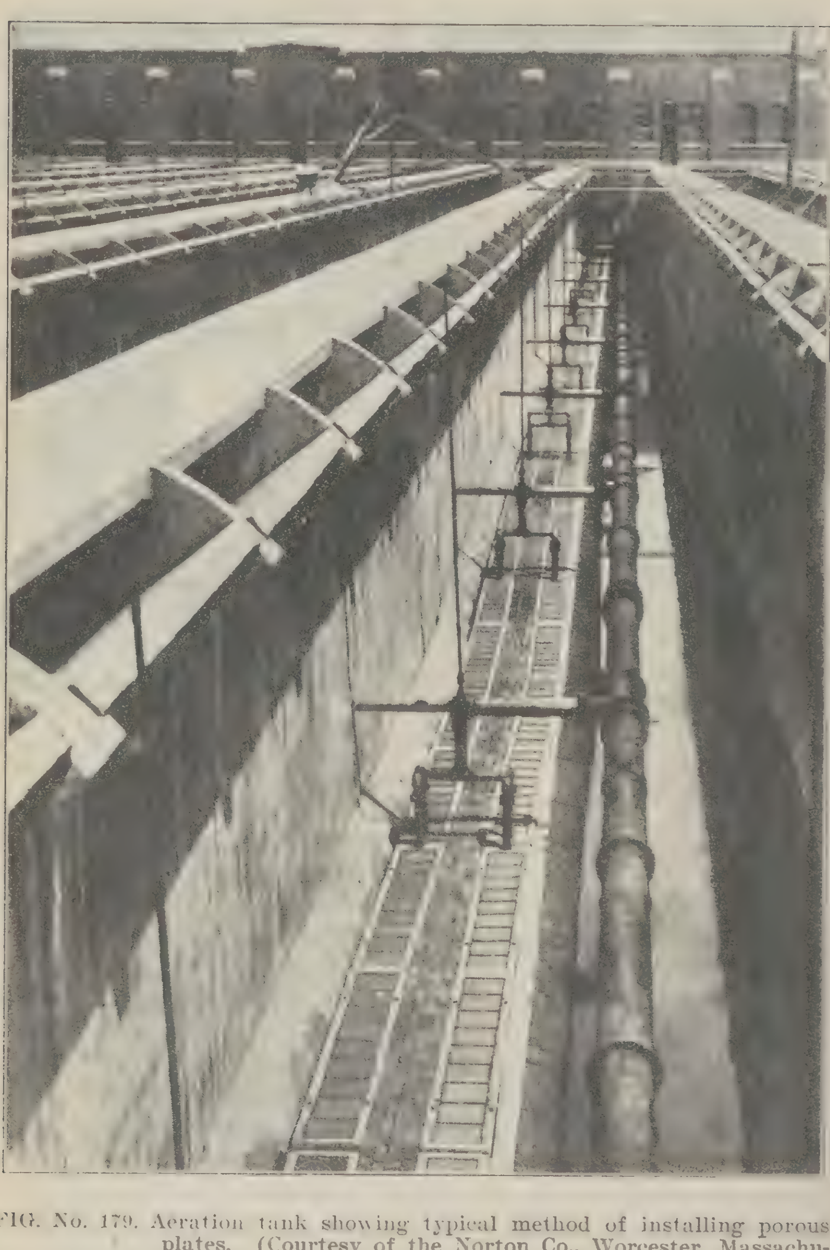


FIG. No. 179. Aeration tank showing typical method of installing porous plates. (Courtesy of the Norton Co., Worcester, Massachusetts).

Preliminary treatment may consist of fine screening or plain sedimentation, or both. Usually, plain sedimentation is employed to remove the grit and the more bulky solids. In some instances, a considerable proportion of the suspended solids are removed by plain sedimentation (page 621). The effluent from the sedimentation tanks is then treated by the activated sludge process.

Aeration. The ordinary aeration tank is a long, relatively narrow concrete basin, the dimensions of which are determined by the duration of the aeration period, the quantity of sewage to be treated and the method used to apply the air. In order to increase the velocity, the tank may be divided by longitudinal baffles.

Diffuser plates and tubes. The sewage is aerated either by diffused air under pressure or by mechanical appliances. Whatever method is used, the object is to mix thoroughly the returned activated sludge (*infra*) and the fresh sewage in the presence of sufficient oxygen in order to maintain aerobic conditions.

Air under pressure from blowers or compressors is applied through porous plate or tube diffusers. The plates and tubes are made of fused alumina or baked quartz sand. The plates are usually one foot square and from 1 to $1\frac{1}{2}$ inches thick. The tubes are ordinarily two feet long with an internal diameter of from 3 to $4\frac{1}{2}$ inches. The wall of the tube is about $\frac{5}{8}$ inch thick (Fig. No. 178).

In some tanks, one or more rows of the diffuser plates are installed along one side of the tank, or along one side of the bottom of the tank. The effect of the air bubbles rising vertically through the slowly flowing sewage is to produce a so-called *spiral flow.* In other instances, the diffuser plates are placed in the bottom of transverse furrows which are separated by concrete ridges, or spacers. In a few plants, longitudinal furrows and ridges are used (Fig. No. 179).

The diffuser tubes are ordinarily installed about four or five feet below the surface of the sewage along one side of the tank, between the wall of the tank and a longitudinal baffle. The sewage mixed with air flows upward between the wall and the baffle and then across the tank and back under the lower edge of the baffle, producing a spiral flow (Figures No. 180 and 181).

FIG. No. 180. Aeration tank showing method of installing porous tubes. (Courtesy of the Norton Co., Worcester, Massachusetts).

FIG. No. 181. Aeration tank at an activated sludge plant. The air passes into the sewage through porous tubes. (Courtesy of the Norton Co., Worcester, Massachusetts).

Mechanical aerators. Mechanical aerators, instead of air under pressure, are frequently employed to aerate and mix the sewage. They consist, generally, of power driven devices which stir the upper portion of the sewage in the aeration tank to a depth which will bring all of the sewage into contact with the air and prevent sedimentation in the aeration tank. A revolving apparatus which produces a spiral flow of sewage is shown in Fig. No. 182. Mechanical aeration may be used in combination with diffused air.

FIG. No. 182. Mechanical aerator. (Courtesy of the Link-Belt Company, Philadelphia, Pa.).

Sedimentation tanks. The sedimentation tanks are concrete basins, usually rectangular in shape. They are relatively deep, so as to provide for temporary storage of the voluminous sludge. They may be equipped with hopper bottoms to facilitate the concentration of the sludge in the vicinity of the sludge pipe in the bottom part of each hopper. In other instances, the floor is sloped so that the sludge deposited on the bottom can be moved to a drainage sump or hopper by mechanical means (page 623).

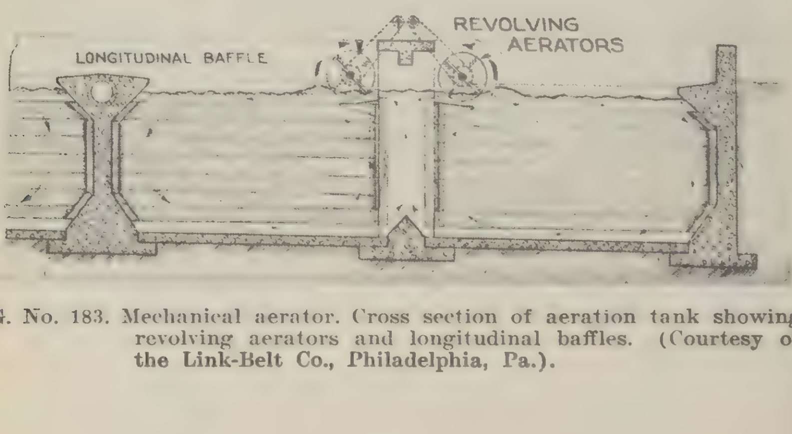


FIG. No. 183. Mechanical aerator. Cross section of aeration tank showing revolving aerators and longitudinal baffles. (Courtesy of the Link-Belt Co., Philadelphia, Pa.).

Operation of activated sludge plants. The activated sludge, which in routine operation after a plant has been started is the sludge obtained from the sedimentation tanks, is added to the raw sewage in quantities which correspond to from 10 to 35 per cent of the volume of the sewage. The average amount is from 15 to 25 per cent. The returned activated sludge is added to the raw sewage as it enters the plant or after preliminary sedimentation.

The flow through the aeration tank is continuous, the detention period being from two to eight hours. During this time, the sewage containing the activated sludge is continuously and vigorously agitated and aerated. If diffused air is used, the air is applied at the rate of from one to three cubic feet of free air per gallon of sewage, or at a minimum rate of 0.2 cubic foot of air per square foot of water surface per minute.

The coagulated sewage passes from the aeration tank into sedimentation tanks where the rate of flow is reduced to about one foot per minute during a detention period of from 30 minutes to 2 hours.

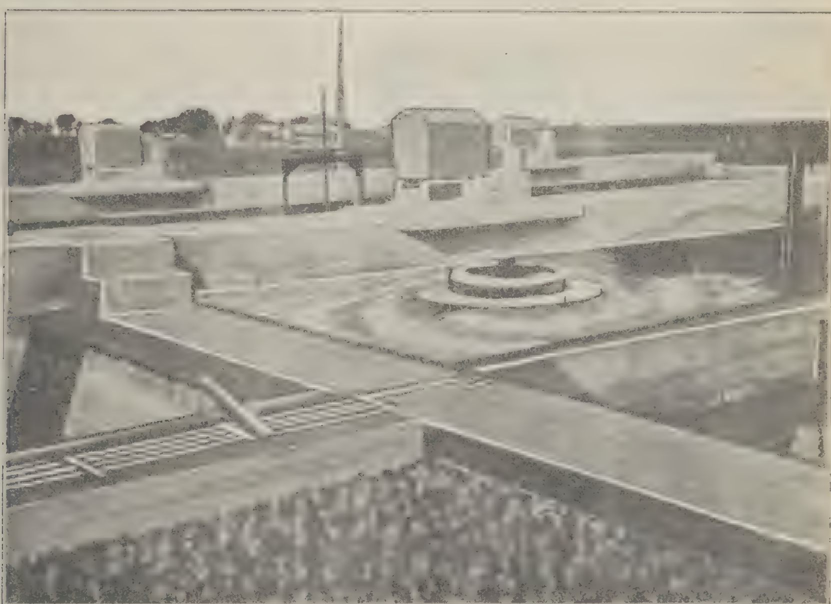


FIG. No. 184. Mechanical aerator of the revolving type (Simplex). (Courtesy of the Simplex Ejector and Aerator Corporation, Chicago, Ill.).

It is essential that all parts of the plant be kept free from deposits in which anaerobic decomposition might occur, as any anaerobic bacterial activity prevents the proper activation of sludge and will seriously interfere with the operation of the plant.

Removal and return of the sludge. The sludge which accumulates in the sedimentation tanks consists of the solids removed from the treated sewage plus the activated sludge applied to the raw sewage. Usually, from 150,000 to 250,000 gallons of sludge are added to each one million gallons of raw sewage (from 15 to 25 per cent by volume). This quantity must be removed from the sedimentation tanks and returned to the raw sewage while the excess, corresponding to the amount derived from the sewage being treated, must be disposed of by other means. The volume of the excess sludge depends on the strength of the raw sewage. Under average conditions, from 10,000 to 15,000 gallons of sludge are produced by the activated sludge process from one million gallons of sewage, as compared with 2500 gallons by plain sedimentation, or 500 gallons by septic tank or Imhoff tank treatment.

The sludge is removed continuously or at intervals from the sedimentation tank by gravity or by pumping. As a rule the sludge passes from the sedimentation tank into a return channel, re-aeration tank, or a sludge distributing well or manhole from which the required proportion is returned to the raw sewage in the mixing channel. The excess is disposed of as waste sludge. Usually, provision is made for the continuous aeration of the returned sludge in the return channel or re-aeration tank.

Under-aeration and over-aeration. Well activated (aerated) sludge contains about 98 per cent water and has a brown or golden brown color. Under-aerated sludge is light brown, thin and voluminous and may contain as much as 99.5 per cent water. The volume of 99.5 per cent sludge is about four times as great as that containing only 98 per cent of water.

Over-aerated sludge may disintegrate and fail to produce coagulation. Neither under-aerated nor over-aerated sludge will settle properly, and both tend to remain in the effluent.

Disposal of the excess sludge (*infra*). The comparatively great volume and its high water content render activated

sludge much more difficult to dispose of than the sludge produced by septic or Imhoff tanks. Ordinarily, the use of sludge drying beds is not practicable because of the long time required for the sludge to dry to a spadeable condition and the extensive drying area rendered necessary by the large volume of sludge. The sludge may be disposed of in lagoons if the space is available.

In many instances, the sludge from an activated sludge plant is stored in separate sludge-digestion tanks where it undergoes anaerobic decomposition and stabilization (page 645). The digested sludge can then be disposed of by the methods described on page 662. Frequently, activated sludge is dewatered by filtering or pressing (page 666).

The sludge produced by the activated sludge process has a high nitrogen content, as compared with other sludges, and is a comparatively good fertilizer. In view of the high operating costs it is desirable that, where practicable, the sludge be dewatered, dried and sold for fertilizer. Frequently, however, the conditions are such that the cost of preparing the sludge for market equals or exceeds its sale value.

Advantages of the activated sludge process. When compared with other methods of sewage treatment, the activated sludge process has the following advantages:

a. It produces an effluent which will not create a nuisance if disposed of without secondary treatment.
b. No offensive odor is produced as there is no septic decomposition.
c. The installation of the plant requires a relatively small space.
d. The sludge has a high nitrogen content.

Disadvantages of the activated sludge process. As compared with other types of sewage disposal plants, the cost of operating an activated sludge plant is considerably higher. The success of the activated sludge process depends upon the exact adjustment of a biological process and requires constant and skilled supervision. Neglect, errors, or inefficiency, even though temporary, will result in the production of a poor sludge and it may require from one to several weeks to re-establish proper conditions for the production of a stable ef-

fluent. Failure or improper adjustment of the biological processes may result in poor flocculation and the discharge of comparatively large quantities of suspended solids in the effluent.

SLUDGE DISPOSAL

One of the principal objectives of tank treatment is the separation from the sewage and separate disposal of a greater or less proportion of the suspended solids or sludge. Sludge is not ordinarily a menace to health because it does not usually come into contact with any medium by which the pathogenic organisms which it might contain could be carried to man. It is, however, prone to produce nuisances and is difficult to dispose of because of the putrescible organic matter which it contains. The characteristics of the sludge with regard to the water content, and therefore the volume, and the offensiveness of the solid material are determined to a considerable degree

FIG. No. 185. Empty sludge beds. (Courtesy of the Pennsylvania Department of Health, Harrisburg, Pa.).

by the kind of tank treatment by which it is produced. These characteristics influence the effectiveness of disposal measures and to some extent determine the type of disposal procedures to be adopted.

Methods of sludge disposal. Sludge may be directly and finally disposed of as such by burial or by lagooning near the point of production. It may be utilized as fertilizer or as filling material subsequent to drying or pressing to remove a part of the water content.

Burial. The sludge may be carried through the sludge pipes directly from the tanks into trenches. These trenches are usually about 3 feet wide and at least 18 inches deep and, when filled to the proper depth with sludge, are back-filled with earth. This method usually requires a larger area than is available in the vicinity of the plant.

Lagooning. The sludge may be carried in pipes or by ditches to a ravine or low area where it is allowed to spread over the surface of the ground to a depth of from one to five or six feet. It is dried by evaporation and drainage. This method of disposal usually requires a larger area of ground than is continuously available and also tends to produce offensive odors.

FIG. No. 186. Sludge beds showing concrete channels with lateral openings and concrete aprons.

Sludge drying beds (Fig. No. 185). The function of a sludge drying bed is to modify the physical character of the sludge, by reducing the water content by drainage and evaporation, so that it can be handled with a spade. Spadeable sludge can be transported to a distance for use as fertilizer, fertilizer base, or as filling material.

The ordinary drying bed consists of underdrains surrounded by a layer of gravel which supports a layer of sand. The underdrains are open joint tile laid on the ground and leading into a main drain. They should be spaced not more than eight feet apart from center to center. The gravel layer is from six to ten inches in depth and consists of crushed stone from one to two inches in diameter around the underdrains and graded to the size of coarse sand at the surface. The sand layer resting on the gravel is from one to twelve inches, usually three to six

FIG. No. 187. Relation of Imhoff tanks and sludge beds. (Courtesy of the Pennsylvania Department of Health, Harrisburg, Pa.).

inches in thickness. The total depth of the bed should be at least twelve inches above the underdrains. The total area is divided into beds of a convenient size, separated by wooden or concrete walls. The surface of the bed used for drying Imhoff tank sludge should have a fall of about one-half of one per cent away from the inlet end. Where sludge from separate digestion tanks is to be dried, the beds should have very little if any slope; that is, not more than two inches in one hundred feet.

The drying bed serves to support and retain the solid constituents of the sludge while providing a means for draining away the water. No purification of the water by filtration or oxidation occurs. The effluent from the drying bed is disposed of by returning it to the primary tank, by dilution in water, or by broad irrigation.

From 0.5 to 5.0 square feet of drying bed surface are required for each person served by a sewage disposal plant, and it is essential that an adequate area be provided wherever practicable. Open beds should have a minimum capacity of from three to five square feet per person for plain sedimentation or septic tank sludge, one square foot per person for sludge from Imhoff

FIG. No. 188. Sludge beds containing dried sludge ready for removal.

tanks or separate sludge-digestion tanks, and five square feet per person for activated sludge plants.

The sludge is spread over the bed to a depth of from six to twelve inches. The spreading may be accomplished by passing the sludge from the sludge pipes, either directly or through a trench, onto a concrete apron from which it flows over the bed. In other instances, concrete channels are installed on the sur-

FIG. No. 189. Small glass enclosed sludge bed. (Courtesy of the Lord & Burnham Co., New York, N. Y.).

face of the bed. Lateral openings in the walls of the channels permit the sludge to flow onto concrete aprons and the surface of the beds (Fig. No. 186).

The length of time required for the sludge to dry to a spadeable condition in open beds depends on the character of the sludge and upon the amount of rainfall to which the sludge is subjected, and varies from ten days to six weeks or longer. Rapid drying can be promoted by the addition of coagulants, such as alum or ferric chloride, to the sludge as it flows onto the bed. When dry, the sludge is removed from the bed, which is then raked and made ready for another application.

FIG. No. 190. Large glass enclosed sludge bed. Also open beds with tracks for cars used in the removal of sludge. (Courtesy of the Lord & Burnham Co., New York, N. Y.).

In order to protect the sludge from the rain and snow, and thus promote more rapid drying, the beds may be covered by a glass enclosed structure, or "glass over" similar to a greenhouse (Fig. No. 190). Glass covered beds require only about one-half of the area of open beds and have the advantage that they can be operated throughout the year despite unfavorable weather conditions. A glass enclosure also tends to decrease odor nuisance by reducing the dissemination of malodorous gases from the drying sludge.

Mechanical dewatering. Where it is impracticable to use sludge drying beds, the sludge may be dewatered by filtration either under pressure or by vacuum.

Sludge presses differ in design and in methods of operation. In the ordinary press, the sludge is pressed or squeezed between metal plates and a portion of the water forced out and through filter cloths. The remaining sludge is removed or drops from the filter cloths in the form of sludge cake. The sludge cake contains from 70 to 80 per cent of water and is similar to loam soil in consistency. In one type of press the plates are covered with rather heavy cloth. The water is forced through the cloth and drained away, while the sludge remains in the press. When the press is opened the sludge cake drops out. In another type, the sludge is placed in burlap bags which are hung between plates and the water pressed out by forcing the plates together.

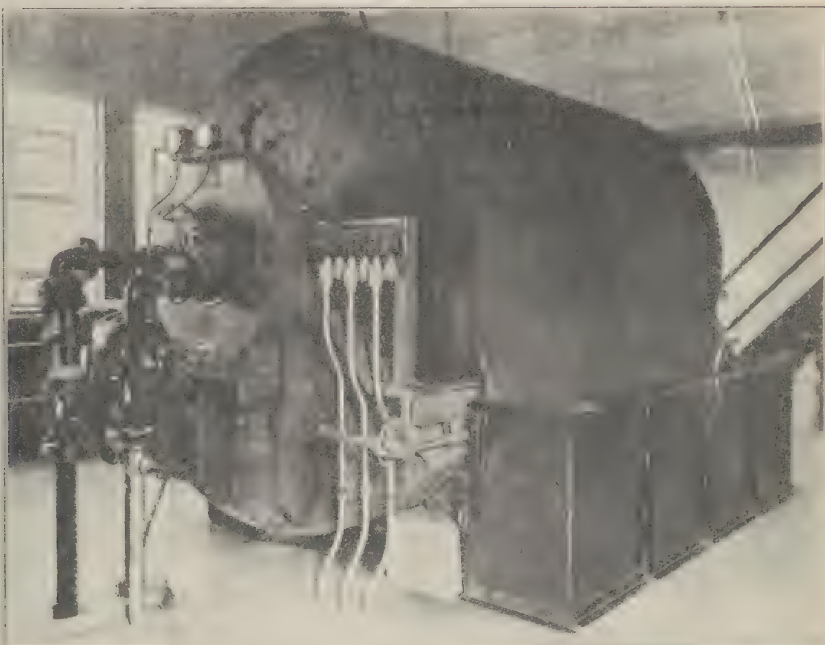


FIG. No. 191. A sludge dewaterer, or vacuum filter. (Courtesy of the Oliver United Filters, Inc., New York, N. Y.).

In a *vacuum filter*, the sludge is subjected to the pull of a partial vacuum which removes a part of the water through the filter material. One such filter consists of a revolving drum, or cylinder, which is partially submerged in a tank containing sludge. The outer shell of the drum consists of the filter cloth or mat. Below the filter cloth, and within the drum, are a series of

compartments within which can be maintained, independently, either a negative or a positive air pressure. As the drum revolves, a partial vacuum is produced in the compartments passing through the sludge. Sludge is picked up and held on the outer surface of the filter cloth and the liquid is drawn through the cloth by suction. The vacuum is maintained while the compartments pass through the upper part of the circle above the sludge and until they again approach the sludge in the tank when the vacuum is released and replaced by positive air pressure. The sludge cake is then removed from the cloth by scrapers and the vacuum is restored (Fig. No. 191).

Sludge which is to be filtered is usually conditioned by the addition of coagulants such as ferric salts or alum.

Sludge can be dewatered by centrifuging, but this method is not used to any considerable extent in the United States.

Fertilizing value of sludge. The constituents of a good fertilizer, that is, nitrogen, potash and phosphoric acid, are contained in sludge but are so combined with other substances that a considerable time elapses after the sludge is placed on the soil before they become available for plant food. For this reason the fertilizing value of sludge is much less than that of commercial compounds, the constituents of which are readily available and immediately released.

The use of sludge as a fertilizer is not ordinarily a practicable measure unless it contains at least three per cent of nitrogen and not more than ten per cent of moisture. However, sludge, with the exception of that produced by the activated sludge process, usually contains much less than three per cent of nitrogen and, under ordinary conditions, cannot be sold as fertilizer. It may be possible to use it as a low grade fertilizer or as filling material. The dried sludge may be used as a base for commercial fertilizer.

SECONDARY TREATMENT METHODS

With the exception of the effluent from an activated sludge or a chemical precipitation plant, the effluents produced by tank treatment usually contain at least 50 per cent of the unstable organic matter originally present in the raw sewage. Any tank effluent may contain large numbers of pathogenic organisms. However, as a result of tank treatment, the organic matter is in a finely divided or liquefied state and is to this extent pre-

pared for stabilization by oxidation. The effluent from a septic tank is septic and contains no oxygen while that produced by plain sedimentation or Imhoff tanks is relatively fresh but will, under certain conditions, become septic in a short time. In many instances, such effluents cannot be directly disposed of by dilution or in the soil without producing a serious nuisance.

The further stabilization of the effluents from tanks is effected by oxidation and nitrification of the suspended and dissolved organic matter by passage through trickling filters, contact beds, or sand filters in which controlled aerobic conditions can be maintained.

TRICKLING FILTERS

(*Sprinkling filters*)

The trickling filter is the most common installation employed for the secondary treatment of sewage (Fig. No. 192). It consists of a bed of broken stone onto the surface of which the sewage is sprayed intermittently in predetermined quantities at definite intervals. The liquid spreads in a film over the surface of the stones and trickles down through the bed to be carried away in underdrains. The large size of the filling material facilitates the penetration of air into the bed so that the sewage is in contact with oxygen at all times. The solids in the sewage tend to adhere to the surface of the stones, forming a gelatinous film containing aerobic bacteria and animal organisms, including many worms. The film also serves to attract and retain the colloidal matter in the liquid. The organic matter in the sewage flowing over the stones of the filter is gradually oxidized by contact with the film so that the filter effluent differs materially from the sewage entering the filter, in that the contained organic substances have been partially stabilized and rendered much less putrescible.

Unloading. A trickling filter does not effect filtration in the sense that suspended matter is permanently removed from the water passing through the filter, as from time to time the film adhering to the rocks slips off and is carried away in the effluent. This process is called *unloading*, and tends to occur periodically and to the greatest extent when warm weather begins in the spring of the year.

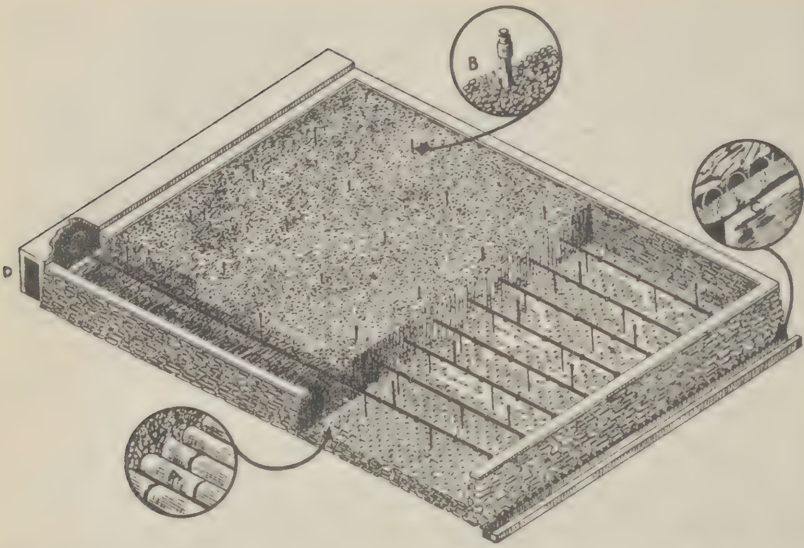


FIG. No. 192. Trickling filter (Schematic). A—Underdrains. B—Riser and nozzle. C—Underdrain and effluent channel. D—Distribution system.

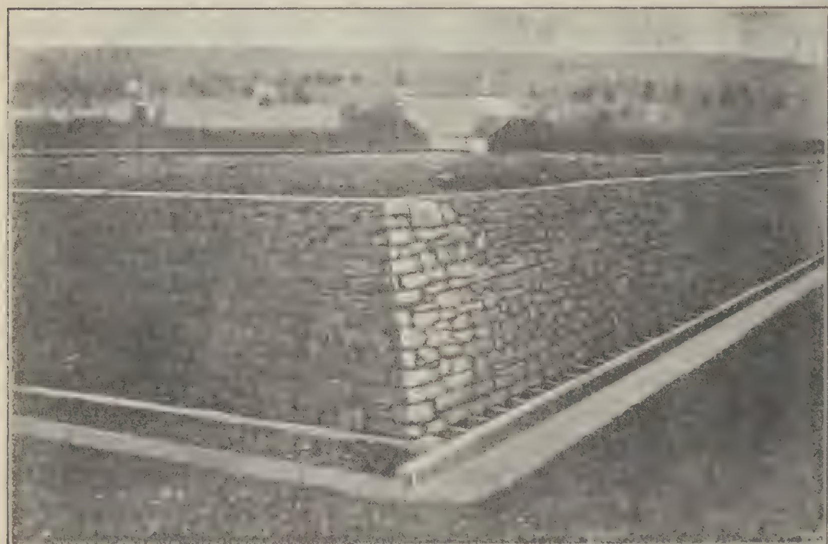


FIG. No. 193. Trickling filter showing underdrain channels. These channels empty into a main effluent channel between the beds.

The quantity of suspended matter in the effluent from a trickling filter varies greatly at different times, but over a period of months or a year, because of the unloading of the filter, the effluent will contain as much sediment as the influent. Furthermore, because of the precipitation of colloidal matter and the organisms in the film on the stones of the filter, the total amount of organic matter discharged in the effluent may be considerably greater than that contained in the influent. The suspended matter in the effluent is relatively stable, but the presence of worms and other living organisms may render it putrescible under some conditions. In many instances, it is necessary to treat the effluent from a trickling filter by plain sedimentation or intermittent filtration through sand in order to remove the suspended organic matter prior to disposal by dilution.

The filtering medium. The filtering material, or filling material, of a trickling filter usually consists of rough, broken stone from 2 to 3½ inches in diameter. Stones as large as four inches in diameter may be used. In some plants the larger stones

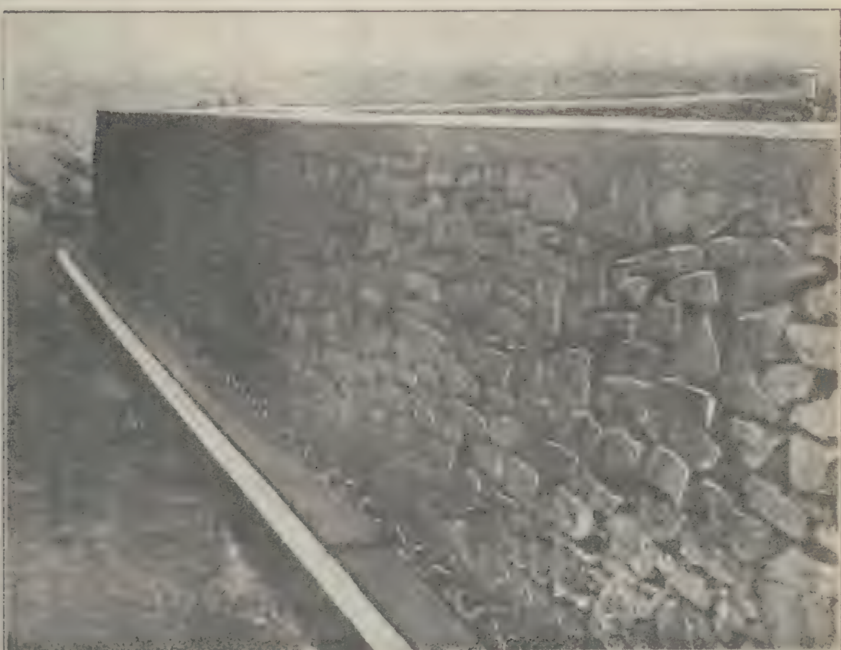


FIG. No. 194. Small trickling filter showing half tile underdrains and effluent gutter into which the underdrains empty.

are placed around the underdrains to prevent the entrance of finer material into the drains. There should be a strict limitation on the permissible proportion of material finer than a specified minimum size. For example, not more than five per cent of the filtering material should be less than one inch in diameter.

Material which does not disintegrate readily should be used in order to obviate packing and the consequent necessity for repairing or rebuilding the bed. Usually, trap rock, granite, quartzite or limestone is employed for this purpose. Crushed slag is sometimes used. In some localities, it may be practicable and much cheaper to construct the major portion of a filter bed from local and less durable stone and use the more expensive material, such as trap rock or granite, only in the construction of the uppermost 12 to 18 inches.

Depth of the bed. Trickling filter beds vary from five to ten feet in depth. In most instances, the depth is about six or seven feet. Certain studies have shown that beds from eight to ten feet in depth are more efficient and can be more economically operated than the more shallow beds.

FIG. No. 195. Trickling filter during construction, showing main and lateral distribution pipes.

Size of the beds. The filter surface area required to treat a given quantity of sewage depends upon the character and strength of the sewage, the rate of application, and the depth of the filter. The rate of application should be not more than 300,000 gallons per acre per day per foot of effective depth. At this rate, a filter seven feet deep has a filtering capacity of 2,000,000 gallons per acre, or 46 gallons per square foot of filter surface per day. Given a filter 7 feet deep, a surface area of 2,200 square feet would be required to treat the sewage produced by 1,000 persons at the rate of 100 gallons per capita per day.

The filter may consist of one bed or of a series of beds separated by concrete walls or embankments. Usually two or more beds are installed so that one can be placed out of service for repairs.

Underdrains (Fig. No. 192). The floor of the filter is usually made of concrete or masonry and supports or contains the underdrains. The underdrains usually form a false floor for the filter and support the stone. They may consist of

FIG. No. 196. Trickling filter during construction, showing lateral distribution pipes and risers.

half tile, either slotted or laid with open joints, or of grooves or channels in the floor which are covered with slabs of concrete or vitrified clay. They should have a fall towards the main drain of not less than one per cent. The fluid spreads over the floor of the filter and is collected and guided toward the main drains by the underdrains. The main drains are usually rectangular, or half-round channels covered with concrete slabs. They may bisect the filter unit or be located at one or both sides. In some instances, an open gutter channel is placed outside of the filter wall and serves as a main drain (Fig. No. 194). From the main drain the sewage flows to the outfall sewer or to a secondary sedimentation tank, or sand filter (page 693).

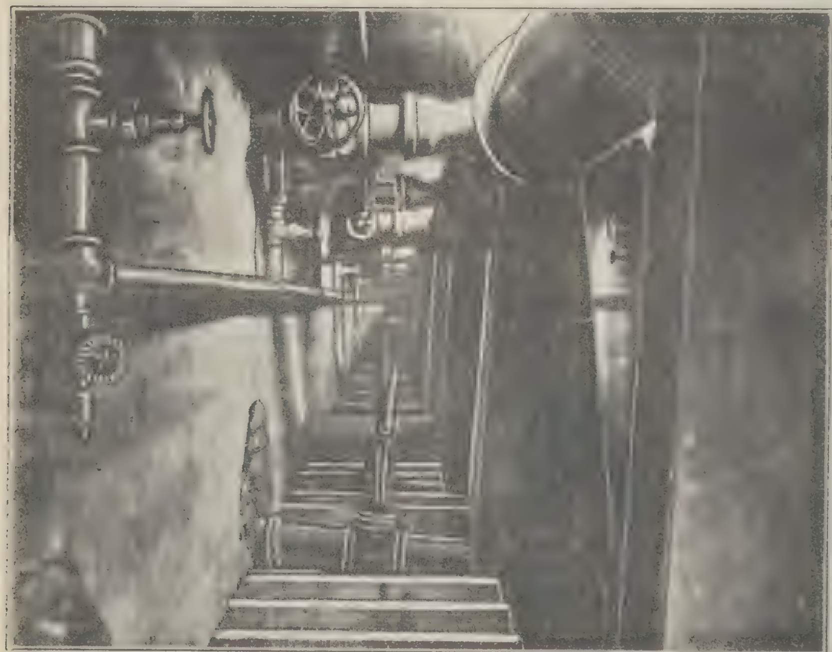


FIG. No. 197. Gallery between two trickling filter beds showing main and lateral distributing pipes. Also underdrain channels emptying into effluent channel.

Ventilation. In order that the filter may function properly, it is necessary that air be present in all parts of the bed at all times. Usually, sufficient air is carried downward by the flow of sewage and there is some ventilation downward

from the surface between the rocks while the bed is resting between doses. However, it may be found desirable to provide other means by which air will gain access to the filter. Openings may be left in the walls of the filter which serve as ventilators, but usually vent pipes with or without revolving cowls, are installed at regular intervals. These vent pipes carry air from above the surface of the filter into the depths of the bed.

Distribution. In the operation of a trickling filter the sewage is distributed over the top of the filter either by spraying nozzles or by movable distributors.

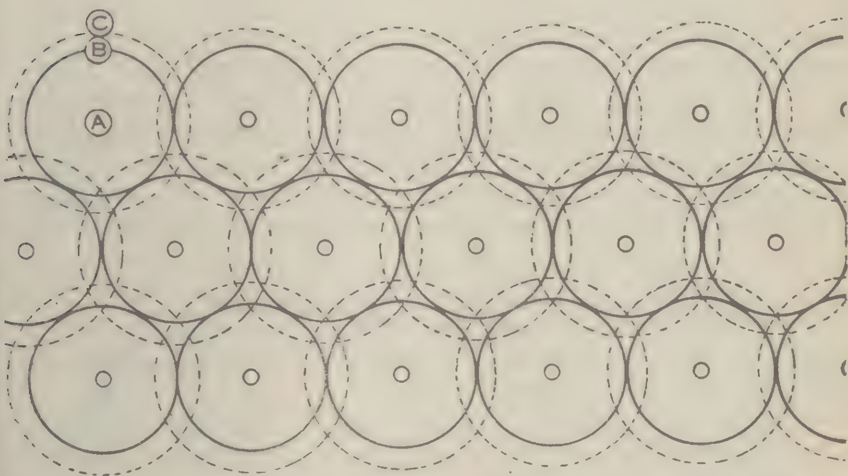


FIG. No. 198. Areas of the surface of a trickling filter sprayed with circular sprays. A—Nozzles. B—Area sprayed if there is no overlapping. C—Area sprayed if there is sufficient overlapping to cover the entire surface of the filter. (This is the usual method).

Spraying nozzles (Fig. No. 192). The sewage is carried to or into the filter bed in a main pipe which may be laid on the floor of the filter, supported on piers in the filter bed, or placed in a pipe gallery between two filter units. Lateral distributor pipes branch off from the main distributor pipe at intervals of from 13 to 15 feet. The lateral distributors are usually four to six inches in diameter and may be placed just above the floor of the filter or anywhere between the floor and the surface of the filter. Where the laterals are located above the floor of the filter they may be supported by uprights, piers, or walls, or laid directly on the fil-

ter medium. Pipe risers, usually three inches in diameter, pass upward from the laterals to from six to twelve inches above the surface of the filter bed, where they terminate in spraying nozzles. The risers are usually spaced at intervals of from 12 to 15 feet from center to center.

The smaller pipes of the distributing system are made of cast iron, and the larger pipes may be cast iron or reinforced concrete.

The spraying nozzles are fixed in the upper end of the pipe risers, and are so designed that they will throw the sewage in a circular or square shaped spray over the surface of the bed. A nozzle producing a circular spray is ordinarily used. The extent of the area covered by the spray from one nozzle depends on the maximum and minimum head (pressure) of the sewage at the nozzles and the height of the nozzle above the surface of the filter. The nozzles should be so located in relation to each other that all the surface of the filter is reached by the spray but with a minimum of overdosage due to overlapping. The nozzles are usually placed at the apices of equilateral triangles and so spaced that there are no areas which are not sprayed (Fig. No. 198). With this arrangement about 10 per cent of the filter surface will be dosed by overlapping sprays. Usually, the nozzles are spaced about 14 feet from center to center.

Moving distributors (Fig. No. 199). The moving distributors are usually either of the revolving or traveling type. The

FIG. No. 199. Rotary distributor as used in distributing sewage effluent over the surface of a trickling filter. (Courtesy of the Pacific Flush-Tank Co., Chicago, Ill.).

ordinary revolving, or rotary, distributor is made with four arms consisting of pipes which are attached to a central vertical cylinder. Each arm has a number of holes on one side. The filter is circular in shape and the arms extend outward from the central cylinder horizontally to and a short distance above the surface of the filter. The sewage flows through the central cylinder into the arms and out through the holes onto the filter, and at the same time forces the arms to revolve over the filter. The sewage as it leaves the cylinder must have a minimum head of from 12 to 24 inches in order to cause the mechanism to revolve.

The traveling distributor is usually designed for rectangular beds and, as the name indicates, travels back and forth above the surface of the filter. Various kinds of traveling distributors have been made. One kind consists of a truss which supports the feed pipes and which travels on rails on either side of the filter bed. The distributor is moved by power from a stationary motor, or from an electric motor placed on one of the carriages.

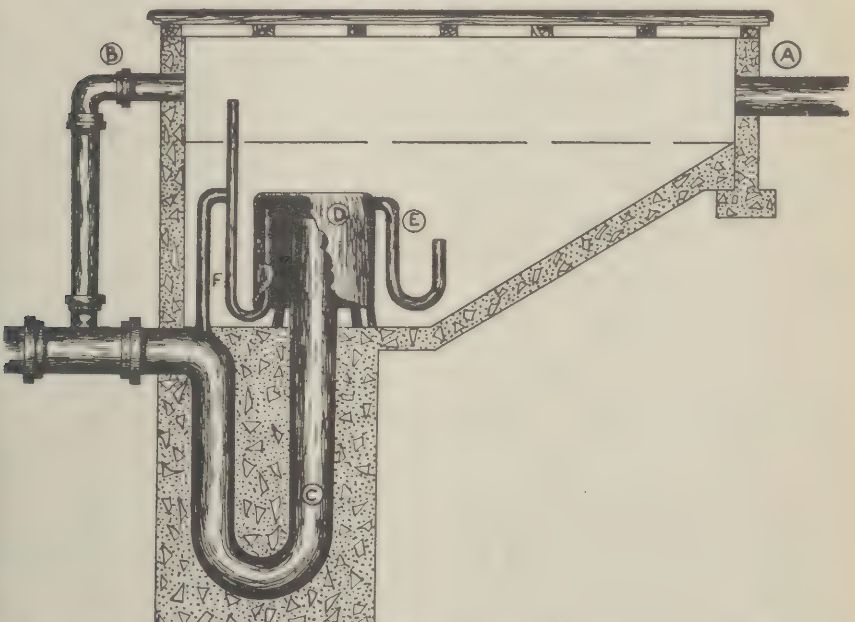


FIG. No. 200. Small siphon and siphon chamber (Schematic). A—Inlet pipe. B—Overflow outlet. C—Main trap. D—Siphon bell. E—Vent pipe. F—Blow-off trap.

Dosing apparatus. The sewage is applied to a trickling filter intermittently in definite, predetermined amounts or doses. The quantity which is to be sprayed on the filter at one application flows from the discharge pipe of the treatment tank or tanks into a dosing tank or chamber. The length of the interval between applications is governed by the time required to collect the quantity of sewage constituting one dose. The dosing tank is emptied into the distributing system of the filter through a siphon or an automatically operated valve. As a rule, some kind of siphon is employed for this purpose.

The basic features of an air controlled siphon are depicted in Fig. No. 200. They consist of the main trap, bell, blow-off trap, vent pipe and air vent. The bell is an iron or concrete cylinder, the upper end of which is closed and the lower end open. It is raised above the floor of the tank and supported on legs or piers. The main trap is a U-shaped pipe, the short end of which is connected with the discharge pipe leading to the distribution system of the filter while the long end extends up into the bell. The blow-off trap is a U-shaped pipe, one leg of which extends up into the bell, while the other leg is connected by one pipe with the discharge pipe and by another with the air above the surface of the water in the tank. The vent pipe is constructed as shown in Fig. No. 200.

When the siphon has discharged and another cycle is about to begin, the main trap is full of water up to the level of the invert of the discharge pipe and the blow-off trap contains water up to the level of the upper end of the leg within the bell. The water in the blow-off trap and the main trap is left there when the breaking of the siphonic action causes the discharge to cease. The vent pipe and the bell contain air.

As the sewage flows into the dosing tank, the water level gradually rises and the air within the bell, which is displaced by the rising water, escapes through the vent pipe until the water level rises above the open end of the short leg. The water then enters and fills the vent pipe so that no more air can pass through it from the bell. As the depth of the sewage in the dosing tank increases, the pressure exerted by the fluid against the air in the bell is gradually increased, forcing the water in the main trap and the blow-off trap down towards their curved portions. Finally, when the level of the sewage in the dosing tank reaches a given height, or the discharge

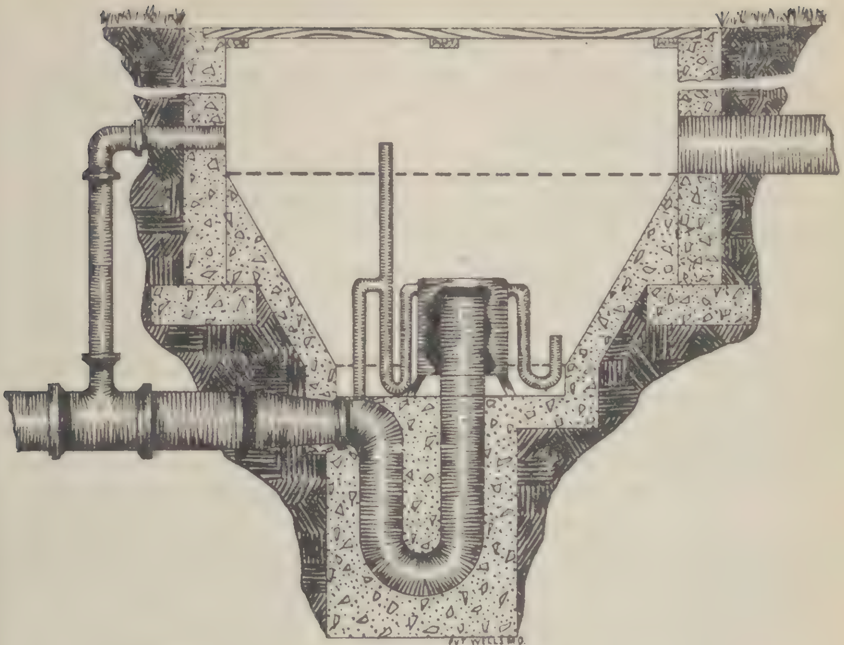


FIG. No. 201. Dosing tank with sloping sides.

line, the pressure within the bell becomes sufficient to force the fluid in the blow-off trap around the curve in the U, thus breaking the seal and permitting the air in the bell to escape. The sewage then enters the upper end of the long leg of the main trap, within the bell, and starts the siphon. The siphon continues to discharge until the level of the sewage within the dosing tank, outside the bell, reaches the curve in the U of the vent pipe when the water seal in the vent pipe is broken and air enters and fills the bell, breaking the siphon and stopping the discharge.

An air vent may be used to equalize the air pressure in the discharge pipe, but it is not an essential part of the siphon.

The basic features described above are practically the same in all siphons, but the details of construction may vary in many ways to meet the local needs. Two siphons may be so installed in the dosing tank that they will discharge automatically in rotation and thus permit two separate filter units to be dosed in rotation. Three or more siphons may be ar-

ranged to discharge automatically in rotation by means of air controlled starting bells or other devices.

Valves, usually of the butterfly type, may be employed in lieu of siphons and are automatically controlled by means of floats or electric motors.

The dosing tank is usually a concrete basin, so located in relation to the filter units which it supplies that when full to the discharge line it provides a head of from six to ten feet on the spray nozzles. The capacity of the dosing tank varies according to the size of the filter unit, or units, it serves and the amount of sewage to be applied to the filter during one dosing cycle (*infra*). The dosing tank for a filter one-fourth acre in extent may have a discharge capacity of from 3,000 to 6,000 gallons, which would supply a dose of from 0.3 to 0.6 gallons per square foot of filter surface during each cycle.

As a rule, the dosing tank is hopper shaped with sloping walls so that the relatively greater capacity of the upper part of the tank will provide a greater head for a longer period of time and the sewage will be distributed evenly over all parts of the area around each nozzle (Figures No. 201 and 202).

Location of filter beds. A trickling filter installation of one acre or less in extent should be at least 500 feet, and a

FIG. No. 202. Trickling filters showing dosing tank and nozzle display phase of dosing cycle.

larger filter 1000 feet or more, from any inhabited building or traveled highway, in order to prevent nuisance due to offensive odors.

The dosing cycle. In the operation of the ordinary trickling filter, sewage is applied only at intervals, not continuously. The interval between applications when no sewage is being distributed is known as the resting period. The period from the time the nozzles begin to spray through the next resting interval until the spray is again in operation is the dosing cycle. The time required for the nozzle display part of the dosing cycle, that is, the period during which the spray is falling on the filter, will vary with the size of the dose, the type of nozzles, and the head on the nozzles. The length of the resting period will vary with the number of doses applied, as the more cycles there are the shorter will be the resting phase of each cycle.

Given a 20,000 gallon discharge per acre, or 0.46 gallon per square foot, and a filtration rate of 2,000,000 gallons per acre per day, the average length of the cycle would be about 15 minutes. In a normal 15-minute cycle there is a 5-

FIG. No. 203. Relation of treatment tank to trickling filter. A—Imhoff tank. B—Trickling filter. C—Chlorinator building. D—Sludge beds.

minute nozzle display period and a 10-minute resting interval.

When the siphon starts there is a maximum head on the spray nozzles which serves to project the sewage to the perimeter of the circle covered by the spray from each nozzle. As the dosing tank empties, the head decreases and the spray falls closer and closer to the nozzles so that the sewage is distributed over the area of the circle around a nozzle from the outer border to the center where the nozzle is situated. The head on the nozzle during one spraying period usually varies from a maximum head of from six to ten feet to a minimum head of from one to two feet.

Uneven distribution of the sewage over the surface of the filter may be due to total or partial clogging of some of the nozzles, with a consequent over-dosage of the area around unclogged nozzles.

In cold weather, the resting period should not be long enough to allow freezing to a degree which would render it difficult or impossible to operate the filter.

FIG. No. 204. Small trickling filter showing rubble walls and ventilation tiles. The sewage is being sprayed near the end of the nozzle display phase of the dosing cycle.

Clogging and cleaning. The spaces between the stones of the filter may become clogged by organic growths of various kinds or by retained organic matter from poorly settled sewage. In some instances this condition may be corrected by resting the filter for a day or two or longer to permit thorough drying. The surface layer of rock may be loosened with picks or forks. A ten per cent solution of caustic soda or calcium hypochlorite may be used to destroy or remove organic growths. The solution is added to the tank effluent as it flows to the filter at the rate of one gallon to each 1000 gallons of sewage. The filter should be treated in this manner for 8-hour periods on alternate days until the growth begins to disintegrate. If it is not practicable to add the chemicals to the tank effluent, the solution may be applied directly to the surface of the filters, at the rate of three gallons of ten per cent solution per square yard of filter surface. A filter unit may be treated a section at a time, the flow of sewage to the area in question being controlled by plugging the nozzles. This avoids placing the entire unit out of service. At times the organic growths can be washed away by the application of water under pressure from a fire hose, or by flooding the filter for 24 hours. Routine chlorination of the filter influent may be employed to prevent or reduce organic growths in the filter (page 699).

The larvae of the filter fly (*Psychoda alternata*), a gray mothlike insect, may cause clogging or impair the efficiency of the filter. These larvae can be destroyed by the application of chemicals as described in treatment of the filter for the removal of organic growths.

The deposits which sometimes form in the underdrains may be flushed out with water under pressure from pipes installed for that purpose, or the water may be applied from a fire hose through openings designed for flushing or through the ventilator pipes.

As the orifices in the nozzles may clog with sediment, particularly if septic tank effluent is being treated, they should be inspected at frequent intervals and cleaned where necessary.

The siphon chamber and the effluent channel should be kept free from deposits on the walls or bottom.

Treatment of trickling filter effluent. While the passage of the sewage through a trickling filter tends to oxidize and stabilize the organic matter, the ultimate quantity of solids is not reduced and may be increased by the presence of organic growth. As the solids tend to accumulate in the filter, and are released by periodic unloading of the filter, the proportion of suspended matter in the effluent varies within rather wide limits.

The organic matter in the effluent from a properly operated trickling filter is relatively stable as compared with that in the tank effluent, but may, nevertheless, under certain conditions, produce nuisances. If the body of water in which the effluent is disposed of by dilution is small or stagnant, putrefaction may occur or sludge banks may form. In the case of other installations, only the effluent produced during periods of unloading will create a nuisance if disposed of without further treatment. The effluent from trickling filters may contain pathogenic bacteria and contaminate the water supply, bathing beaches, or shellfish.

In some situations, the local conditions are such that it will be necessary to provide for the treatment of the filter effluent to remove the suspended solids or prevent the transmission of pathogenic organisms. The measures employed for

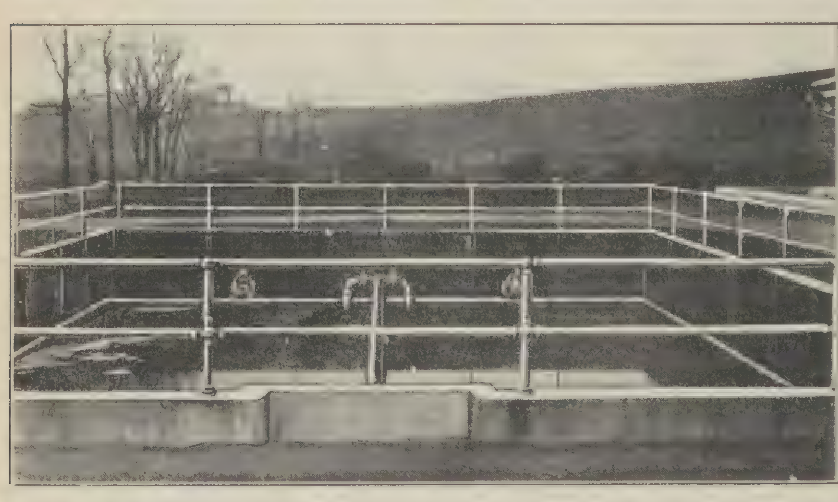


FIG. No. 205. Secondary sedimentation tank used to treat the effluent from a trickling filter.

this purpose consist of sedimentation, sand filtration, and disinfection (page 699).

Secondary sedimentation. About 50 per cent of the suspended solids can be removed from the filter effluent by passage through secondary sedimentation tanks. These tanks are similar in construction to the primary plain sedimentation tanks, except that they are usually shallower. They are operated in the same manner as any sedimentation tank (page 621). Usually, the detention period is from thirty minutes to two hours.

While the sludge from secondary sedimentation tanks is relatively stable, it is usually disposed of with the sludge from the primary tanks.

Sand filtration (page 693). In instances where further bacterial reduction is desirable, intermittent filtration through sand beds may be utilized to remove the suspended solids and the bacteria.

Efficiency of the trickling filter. Properly constructed and operated trickling filters should produce an effluent which is stable under all conditions. In practice, the degree of stability attained depends on the depth of the filter bed in relation to the dosage, the uniformity of distribution, the character of the influent, the temperature, and other factors incidental to the operation of the filter. The relative stability of the effluent from the average filter should be at least 90 per cent and the biochemical oxygen demand not more than 30 parts per million. Pathogenic organisms are not necessarily destroyed by tank and trickling filter treatment and disinfection of the filter effluent may be required.

The efficiency of a trickling filter should be determined by frequent tests for stability (page 710) and biochemical oxygen demand. The color of the growth on the walls of the underdrains and effluent channels may be used as a rough indication of the efficiency of the filter. A green growth indicates that the filter is functioning effectively while a grayish colored growth is an indication that the effluent has not been properly stabilized.

CONTACT BEDS

A contact bed is a watertight basin filled with broken stone or other material. The contact bed differs from the trickling filter mainly in the methods of operation, the basic principles involved in the purification of the sewage being the same in both. The bed is filled with sewage which is held quiescent in contact with the stones for a predetermined period of time. The suspended solids, together with some of the colloidal matter and dissolved solids, are deposited on and adhere to the surface of the stones, forming a jelly-like film which remains when the bed is drained. When the sewage is withdrawn, the bed is allowed to stand idle for a time. During this resting period the air, which was drawn into the space between the stones when the bed was drained, is in contact with film on the surface of the stones and the aerobic organisms in the film oxidize and nitrify the retained organic matter into more stable organic or mineral compounds.

The basin is uncovered and the walls and bottom are usually made of concrete. The bottom has sufficient slope to provide drainage.

Contact material. The contact material usually consists of pieces of rough, hard, durable stone, such as trap rock, granite or hard sandstone, although slag, cinders, or coke may be used. The contact material varies in size in different plants from one to four inches in diameter, the average being two to three inches. If the sewage contains comparatively large quantities of suspended matter, the contact material should be relatively larger. The depth of the bed from the surface to the underdrains is usually four to six feet. It should not be less than three nor more than six feet. Greater depths render cleaning more difficult and the increased weight tends to make the bed more compact.

Underdrains. The underdrains should be so constructed that the bed can be drained as quickly as possible without mechanical disturbance of the deposited material. It should be possible to drain the bed in 30 minutes or less. The underdrain system may be similar to that described for trickling filters, or it may consist of half tile. In other instances, the underdrains consist of channels covered with perforated slabs. These channels are placed several feet apart and lead into main collecting drains.

FIG. No. 206. Contact bed installation showing primary beds on the left and secondary beds on the right, with effluent channel from the tanks between primary and secondary beds.

Distribution system. Several methods are employed to distribute the sewage to the beds. The distributing system may consist of main pipes with branching laterals laid on the bottom, or in the contact material between the bottom and the surface. The sewage escapes from the laterals through suitable openings and fills the bed to, or nearly to, the surface.

Wooden or concrete troughs may be laid on the surface of the bed from which the sewage overflows onto the surface of the contact material or passes through screened openings in the sides of the troughs onto or into the bed. One central trough may be employed, usually running diagonally across the bed, or there may be smaller lateral troughs branching off from a main trough. Individual troughs may radiate from a distributing or dosing chamber. The troughs may contain gravel which retains a part of the suspended solids.

The sewage is usually conveyed from the treatment tanks to the beds in an open channel from which the sewage passes to a dosage tank or to dosage chambers for individual beds. The flow of sewage from the dosage chamber or chambers is controlled by automatic devices, or by manually operated valves or gates. Usually, for the smaller installations at least, timed siphons are employed to control the inflow and outflow of sewage (page 678). In the larger plants where labor is avail-

able for supervision, hand controlled valves or gates may be employed for filling or draining the beds.

Size and number of beds. A clean contact bed has a capacity of from 125,000 to 150,000 gallons per acre per day per foot of effective depth, or an average capacity for a bed from 4 to 5 feet deep of 500,000 gallons per acre per day, or about 11.5 gallons per square foot of surface per day. The capacity of a bed, however, diminishes gradually from the time it is placed in service until it either reaches a stable stage or becomes inoperative. Provision must, therefore, be made for a decrease in capacity, and also for cleaning the clogged beds.

As the individual contact bed is operated by the fill and draw method with a relatively long resting period, and as the flow of sewage through the treatment tank is continuous, there must be, except in a very small plant, two or more beds in order to provide an outlet for the flow from the tanks. In the small plants, the dosing tank may be made large enough to retain the sewage during a cycle so that only one bed will be required. Usually, there are at least three beds so installed that one can be discontinued for repairs or cleaning without rendering it necessary to by-pass a part of the sewage. In order to provide the necessary flexibility in operation, the individual beds are small, as compared with trickling filters, being seldom more than a quarter of an acre in extent for the larger plants and less in the case of small installations.

Frequently, it is necessary, in order to secure a satisfactory effluent, to provide for multiple contact by passing the sewage from a first or primary bed directly into a secondary bed and sometimes from the secondary bed into a third bed. The third bed is seldom needed and, usually, the head required for its operation renders it impracticable. The beds are built in series, so that the bottom of the primary bed is higher than the surface of the secondary bed. The primary bed drains by gravity into the secondary bed, the flow usually being controlled by timed siphons.

Operation of contact beds. The contact bed is operated in cycles, each cycle consisting of four phases, the filling period, the contact period, the draining period and the resting period.

The effluent produced by the tanks in a given period of time must be treated by the contact beds during the same

length of time. Consequently, the length of the complete cycle is governed by the amount of sewage and the capacity of the beds. As the time required to fill or to drain a bed remains practically constant in a given plant, variations in the length of the cycle affect the contact and resting periods. The time allotted for the completion of the cycle should be not less than six hours and preferably more. The average time in many plants is about eight hours.

The operation of filling or draining the bed does not influence the biological processes concerned in the purification of sewage and should be completed as rapidly as possible without disturbing the sediment deposited on the contact material. Usually, from 45 minutes to two or three hours are required for filling and from 15 minutes to two or three hours for draining. The time required varies within limits with the operating conditions and with the design of the plant concerned.

The contact period varies from 30 minutes to two hours. During this time, while the sewage lies quiescent in the voids of the bed, the suspended matter settles onto the surface of the stone and some of the colloidal and dissolved organic matter is absorbed by the film of deposited material. The air is forced out of the bed by the entering sewage so that only the oxygen in the sewage and in the nitrates contained in the film is available for the support of aerobic organisms during the contact period. When this supply of oxygen is consumed, putrefaction tends to occur due to the action of the anaerobic and facultative bacteria. Consequently, the contact period should be such that maximum sedimentation will be obtained, but exhaustion of the oxygen required by the aerobic organisms will be avoided. In a mature bed, the contact period should not, therefore, ordinarily exceed two hours and usually 30 minutes to one hour is sufficient, as determined by tests for stability and biochemical oxygen demand.

The resting period should be at least four hours and as much longer as may be practicable. Variations in the quantity of sewage flowing to a contact bed affect principally the duration of the resting period, the time required for the other periods of the cycle being more or less fixed for a given plant. Consequently, the length of the resting period is determined

mainly by the capacity and design of the beds in relation to the amount of sewage.

The greater proportion of the biological reactions by which the oxidation of the retained organic matter is accomplished occurs during the resting perod. At this time aerobic organisms, which are present in vast numbers, receive an ample supply of oxygen from the air which was drawn into the bed by outflowing sewage. Therefore, within limits, the efficiency of the contact bed as an oxidizing agency varies directly with the length of the resting period.

FIG. No. 207. Contact beds showing pooling caused by clogging.

Clogging. A contact bed eliminates some of the deposited material by unloading into the effluent, but unloading does not occur to the extent that it does from a trickling filter (page 669). On the contrary, the deposits tend to remain in the bed gradually filling up the spaces between the rocks until the bed is filled or, as usually happens, a balanced condition is reached where the effluent contains practically the same quantity of solids as the influent. At times, the contact material slowly becomes compact or disintegrates and accentuates the clogging process. The growth of organisms within the bed may also be a factor in clogging.

Clogging, with a consequent loss of capacity, begins as soon as a bed is placed in operation and may continue until the bed will no longer function, or it may cease after a time and the capacity of the bed decreases but slowly thereafter.

Clogging may be controlled to some extent by the removal of a part of the coarser suspended solids by straining the influent through gravel or cinders in the distribution troughs, or at the point where it enters the distribution system in the interior of the bed. When caused by overdosage or by organic growths, clogging may be remedied by longer rest periods, or by a rest period of from one to two weeks. In other cases, it is necessary to tear down the bed and rebuild it with new or cleaned contact material.

Cleaning beds. Under average conditions, the decrease in capacity due to clogging will render it necessary to clean a contact bed at intervals which vary considerably in length, but usually average about five years. This is generally done by removing the contact material from the bed and washing away the deposited sediment from the pieces which have not disintegrated. It is usually cheaper to wash the contact material and use it again than to purchase a new supply. The bed is then rebuilt with washed material, together with such new material as may be necessary to replace the disintegrated pieces.

Maturing beds. When a clean bed is put in service there is no film on the surfaces of the contact material to retain newly deposited material, absorb the colloidal and dissolved organic matter or promote oxidation. This film is developed rather slowly and the organisms necessary for oxidation must be established before a stable effluent is produced with a normal cycle of operation. It requires from several weeks to months to develop a film, or mature the bed, to a point where the maximum degree of oxidation is obtained. During this period the stability of the effluent may be lowered to a degree which will result in the production of nuisances. Such effluent may be treated further by passage through another contact bed or by chlorination. In the operation of a clean bed, a more stable effluent can sometimes be produced by lengthening the contact period. As the bed matures, the contact period is gradually decreased until a stable effluent can be produced by a normal period of from one-half hour to one hour.

Care of beds and appurtenances. The influent channels, dosage tanks and siphons should be kept clean and free from de-

posits. The production of odors can be reduced by so dosing the beds that the sewage does not form pools on the surface. Odors are less apt to occur in beds in which the distribution system is below the surface. If the surface distribution troughs contain gravel, it may be necessary to remove it at intervals and replace it with a clean supply in order to prevent odors or clogging.

Efficiency of contact beds. Under average conditions, well operated double contact beds will produce a stable effluent which can be disposed of without nuisance. From 70 to 90 per cent of the putrescible suspended matter is removed and the biochemical oxygen demand should be reduced to 30 parts per million or less. The effluent may, however, still contain pathogenic organisms. Ordinarily, it is not necessary to treat the effluent, except in cases where the danger of contaminating untreated water supplies, shellfish or the water on bathing beaches renders disinfection desirable.

Comparative efficiency of contact beds and trickling filters. Much of the suspended matter which is removed from the sewage by contact bed treatment is retained indefinitely in the bed while that removed by the trickling filter eventually re-enters the sewage in a more stable form and is carried away by the effluent. Consequently, the effluent from a trickling filter contains more suspended matter than that produced by a contact bed, which may, under certain conditions, render it necessary to treat the trickling filter by sedimentation or other methods prior to final disposal. However, if the effluent from a trickling filter is subjected to secondary treatment, it is more uniformly stable than contact bed effluent. The effluent from a trickling filter has a considerably higher dissolved oxygen content than that obtained from contact beds, and this factor may be of importance when the sewage must be disposed of in a relatively small body of diluting water.

A contact bed produces less odor than a trickling filter and for this reason can, at times, be employed in localities where the installation of a trickling filter would be undesirable.

Usually a contact bed requires somewhat less head than a trickling filter. The trickling filter is, however, better adapted for variations in flow or in head.

The average rate of operation of a contact bed is 500,000 gallons per acre per day, as compared with 2,000,000 gallons per acre per day for a trickling filter. The cost of installing a contact

bed plant is, therefore, greater than that of a trickling filter plant of equal capacity and more space is required. The loss of capacity, and the necessity for relatively frequent cleaning of the contact material is apt to render the operation of a contact bed plant considerably more expensive than that of a trickling filter.

Contact beds may be employed to an advantage in small plants where it is difficult to secure the head necessary for the operation of trickling filters, and also where it is impracticable to isolate the plant so that the odors from a trickling filter will not constitute a nuisance. Trickling filters are usually found to be more satisfactory for the larger installations, where the required head can be made available without pumping.

INTERMITTENT SAND FILTRATION

The intermittent sand filter is a bed of sand to which settled sewage is applied in intermittent doses. During the intervals between applications, air enters the interstices of the filter and provides oxygen for the support of aerobic organisms. The filter consists essentially of an underdrained sand bed which is usually constructed for the purpose, but a natural deposit of sand may be utilized.

Natural sand deposits. If a natural sand deposit is available *in situ*, it is converted into a filter by stripping away the surface soil and removing all trees, roots, grass and large rocks which would interfere with the flow of sewage into the sand. The surface of the sand is then graded and smoothed, and divided into beds of suitable size by earthen embankments or partitions. Where the sand is stratified in layers of coarse and fine sand, the latter should be at the surface. If the fine sand is in the depths of the filter with coarse sand on top, clogging will occur in the fine sand rather than on the surface where it can be more easily corrected. In some instances, it may not be necessary to underdrain the sand, the sewage being absorbed and carried away by the ground water. Usually, however, an underdrain system must be provided to collect the sewage for transportation to a place of ultimate disposal.

Artificial sand beds. The artificial sand filter consists of rectangular or square sand beds which are separated from each other by earthen embankments or partitions. The sand is usually from two to four feet in depth above the underdrains.

The effective size of the sand should be between 0.2 and 0.5 millimeters with a uniformity coefficient of not more than 3.0 (page 254).

The size of the individual beds varies from one-fourth of an acre, or less, to two or more acres, depending on the size of the plant, the character and the quantity of sewage treated, the topography, and the method of operating. The filter usually consists of a number of beds, but two or more are always installed so that one or more may be placed out of service for cleaning or repairs without seriously interfering with the operation of the plant.

The filter as a whole is inclosed by an earthen embankment or wall of masonry or concrete extending about 24 inches above the surface of the sand. In order to afford access to the beds for removal of surface deposits, the embankment on one or more sides may be wide enough to support a roadway or, in the larger plants, a roadway embankment may be placed between alternate rows of beds. Where roadway embankments are not employed, the beds are separated by earthen or masonry walls extending about 18 inches above the sand.

Underdrains. The underdrain system is usually arterial in form and that for an individual bed is composed of lateral drains leading into a main collecting drain.

In artificial filter beds, the lateral underdrains are placed on the bottom of the filter or in shallow trenches in the floor. In natural beds, trenches are dug to a depth of from four to five feet and the drains placed on the bottom. In both types the lateral underdrains are spaced from 10 to 30 feet apart and laid with a fall of 0.5 per cent or more towards the main collecting drain.

The lateral underdrains usually consist of vitrified clay pipe laid with open joints, the ends being separated by a space of from one-fourth to one-half inch, to facilitate the entrance of the sewage into the pipe. They are surrounded by from 8 to 12 inches of gravel to prevent the sand from being carried into the drains. The gravel is graded from the pipe outward, the inner layer being from 1 to 2½ inches in diameter, while that at the outer surface next to the sand is one-fourth inch or less in size. The trenches in natural filters are back-filled with sand. The main collection drain which receives the sewage from the lateral underdrains varies in size according to

the quantity of sewage and the size of the bed, but is usually at least eight inches in diameter. It may be laid with open or tight joints and placed either centrally or in the embankment at the end or side of the bed.

Distributing system. In the operation of an intermittent filter the sewage is applied at a relatively rapid rate for a short period of time. Usually, the sewage to be filtered first enters a dosing chamber or tank from which it is carried to the beds in vitrified clay or cast iron pipes. Several different

FIG. No. 208. Intermittent sand filter for small Imhoff tank installation. Circular Imhoff tank in the foreground beyond which are two circular dosing chambers. Sewage is distributed by troughs laid on top of sand bed.

methods have been devised to distribute the sewage on the bed. A flat bottom, tapering, concrete trough laid on the surface of the sand may be used. The sewage enters the wide end of the trough and escapes onto the surface of the bed through openings placed at intervals in the sides of the trough. An arterial system of troughs may be employed in which the lateral troughs branch off from a main or central trough at right angles or acute angles. These troughs should be made of concrete, and are laid on the surface of the sand. Wooden troughs tend to float out of position.

Distribution may be effected by providing a concrete or masonry apron below the outlets of the pipes from the dosing

chamber, against which the sewage impinges and flows out over the bed. Four such distributors may be used simultaneously, one being placed at or near each corner of the bed, or two are spaced equidistant on the long sides of the bed.

The main collecting drains may join the outlet pipe between the beds, at the lower end of the filter, or at a point beyond the filter area.

Operation of intermittent sand filters. In the purification of sewage by filtration through sand, the coarser particles are removed by mechanical straining and the suspended and dissolved organic matter is oxidized into stable mineral or organic compounds by the action of aerobic nitrifying bacteria. The coarser solids are retained on the surface and in the upper part of the sand bed where they are subject to the action of the nitrifying bacteria. The colloidal and dissolved organic matter forms a gelatinous film on the sand grains within which, in properly operated filters, are vast numbers of nitrifying and other aerobic organisms. The effectiveness of the intermittent filter as a purification agency depends on the presence of these organisms in sufficient numbers to oxidize and nitrify the organic matter in the sewage applied to the filter.

The factors necessary for the cultivation of the bacteria and the maintenance of maximum bacterial activity are the presence of food, an ample supply of oxygen and the proper temperature. The food is furnished by the organic matter in the sewage. If the filter is properly operated, sufficient oxygen is derived from the air drawn into the filter. When a dose of sewage is applied to the filter, the air is driven from the interstices of the sand, and as the liquid sinks into and through the sand a fresh supply of air is drawn into the spaces between the grains. The optimum temperature for the nitrifying bacteria is between 28°C. and 37°C. (82.4°F. to 98.6°F.). The heat generated by the sewage is sufficient to maintain bacterial activity, even during the colder months, although nitrification decreases and increases with the temperature.

Rate of filtration. The quantity of sewage which can be efficiently treated by filtration through a bed of given size depends on the character of the sewage, the type of filter, and operating conditions. Under favorable conditions, raw domestic sewage can be filtered at a rate of from 25,000 to 75,000 gallons

of sewage per acre per day. The filtration rate for effluents from plain sedimentation, Imhoff or septic tanks usually ranges from 75,000 to 150,000 gallons per acre per day. The rate of filtration for effluents from trickling filters or contact beds may be as high as 400,000 gallons per acre per day.

Dosage. In dosing a filter bed it is desirable that the volume of sewage to be placed on the bed be applied as rapidly as possible. Usually, the sewage is collected in a dosing chamber or tank from which it is released at predetermined intervals by means of siphons (page 678). Manually or mechanically operated valves or gates may be used instead of siphons.

The dosing rate is about one cubic foot of sewage per second for each 5000 square feet of filter area until the surface of the filter is flooded to a depth of from one to three inches, allowance being made for absorption during application. The average dose is, therefore, from approximately 27,000 to 81,000 gallons per acre.

The liquid disappears below the surface of the sand in from 20 minutes to several hours, depending on the extent to which the sand is clogged with retained solids. The time between doses varies according to the size of the dose and the capacity of the filter, but must be sufficient to permit oxidation of the organic matter removed from the sewage.

Clogging. The suspended matter in the sewage is caught and retained on the surface of the sand and in the sand close to the surface. If crude or screened sewage is applied to the filter, the coarse, heavy solids will form a surface mat which in time will become sufficiently thick and compact to interfere with the absorption of the sewage and the entrance of air. The finely divided suspended matter in the effluents from settling tanks tends to penetrate more deeply into the sand and to form a surface mat which is comparatively light and thin. Usually, no distinct mat is formed by the effluents from trickling filters.

When sewage is applied to clean filters it sinks rapidly into the sand near the outlets of the distributing system and fails to spread out and cover the bed. As the surface of the sand in the vicinity of the outlets becomes clogged with retained solids, it becomes less permeable so that the liquid is well distributed before much of it is absorbed into the sand. A certain amount of clogging is, therefore, essential for the efficient operation of a filter.

Cleaning. Clogging to a degree which renders cleaning necessary is indicated by slow absorption of the sewage, or pooling of the liquid on the surface, and by depreciation in the quality of the effluent. The surface mat should be removed whenever it becomes thick and compact enough to decrease seriously the efficiency of the filter. This is done by permitting the mat to dry and then scraping or rolling it free from the sand. When the surface of the sand bed becomes clogged with the finer particles from the sewage, it is cleaned by the removal of a thin layer of sand, one inch or less in thickness. Flat, wide shovels may be used for this purpose. Instead of removing a layer of sand, the surface of the bed may be lightly raked to a depth of not more than one inch. Deep raking will carry the solids into the bed and render future cleaning difficult. Generally, after several rakings a thin layer of sand must be removed.

The frequency with which a filter must be cleaned or the surface mat removed is determined by the amount of suspended matter in the sewage and the rate of filtration. As a rule, about one inch of sand must be removed each year.

The bacterial activity of the filter may be impaired by overdosage or insufficient aeration, as evidenced by a decrease in the stability of the effluent. This condition may be corrected by placing the filter out of service and allowing it to rest for from several days to as long as six to eight weeks.

Winter operation. Freezing weather is a serious obstacle to the operation of an intermittent sand filter. Snow or ice may render a filter bed impermeable by freezing the sewage before it sinks into the sand.

Snow or ice on the filter may be melted, or freezing prevented, by the heat derived from large doses of sewage. In other instances, the surface of the filter is furrowed, the furrows usually being from 6 to 12 inches in depth and from 30 to 36 inches from center to center. The ridges between the furrows support the ice so that the sewage flowing in the furrows beneath is absorbed by the sand.

The filters clog easily in cold weather and freezing interferes with cleaning. The cold decreases the bacterial activity within the filter so that, in any event, it is seldom that the effluent produced in winter is as stable as that obtained during the warmer seasons.

Efficiency of the intermittent sand filter. The intermittent sand filter is capable, when properly operated, of removing from 95 to 97 per cent of the suspended matter contained in the influent. The effluent is clear and stable. It may, however, contain pathogenic organisms.

The field of usefulness of artificial sand filters is limited by the large area required, the cost of construction, and, in the colder sections, by the decreased efficiency in winter. Where available, natural sand deposits are frequently utilized for the treatment of crude sewage by intermittent filtration, but artificial sand filters are employed principally in the final treatment of effluents from trickling filters, Imhoff tanks, or septic tanks. An area of at least one acre of filter surface is necessary for the filtration of the crude sewage produced by 1000 troops. About one-half of an acre is required to filter the same sewage after it has been subjected to preliminary treatment.

CHLORINATION

(*Disinfection*)

None of the sewage treatment methods which depend upon biological reactions or mechanical procedures will eliminate all of the pathogenic organisms from the effluent. Disinfection with a chemical is the only economically practicable method of removing all pathogenic organisms from sewage effluents, and chlorine or chlorine compounds are universally employed for this purpose. Chlorination of sewage is also employed to inhibit the decomposition of sewage effluents during tank treatment, and to eliminate odors.

Adequate chlorination will render sewage harmless in so far as the transmission of disease is concerned. However, as the purification of water, rather than the purification of sewage, is depended upon to prevent the transmission of pathogenic organisms from the sewage to man, the control of nuisances and not the removal of pathogenic organisms is usually the first consideration in determining the methods to be employed in treating or disposing of sewage. Consequently, chlorination is usually employed to facilitate subsequent treatment and to prevent or reduce nuisances. Sewage may, how-

ever, be chlorinated to destroy pathogenic organisms under circumstances which render it necessary to protect bathing beaches or shellfish beds, or to safeguard the riparian rights of a civilian population.

If raw sewage is chlorinated prior to tank treatment, the separation of the settleable solids from the liquid is more complete, the biochemical oxygen demand of the effluent is reduced, and the production of odor nuisances due to septic decomposition during tank treatment is minimized or prevented.

When chlorine is added to sewage it inhibits bacterial activity and retards the progress of biological processes. Chlorination alone will not prevent the ultimate decomposition of the organic matter in sewage and will not, therefore, prevent the deposition of solids in the water or the ultimate creation of nuisances due to odors. However, chlorination may be employed to prevent or control the development of nuisances where there is insufficient diluting water. Investigations have shown that chlorination will effect an actual decrease in the biochemical oxygen demand of the effluent from sewage treatment works and thus permit satisfactory disposal in a smaller volume of diluting water. Where the effluent is discharged into a stream the volume of which is inadequate for dilution purposes at the point of discharge, chlorination may be employed to delay decomposition long enough for the sewage to be carried down stream to a point where there is sufficient water to effect satisfactory dilution.

The offensive odor caused by septic decomposition is largely due to hydrogen sulphide. This is particularly true of those odors which are perceptible at some distance away from their point of origin. Chlorine combines with hydrogen sulphide to form substitution compounds which are odorless or have odors which are not offensive.

The principles involved in the chlorination of sewage are the same as those concerned in the chlorination of water (page 289). Either liquid chlorine or a solution of calcium hypochlorite can be used. The methods of applying the chlorine are basically the same as those described for the purification of water, due allowance being made for the larger quantities required in the chlorination of sewage (Fig. No. 209). A

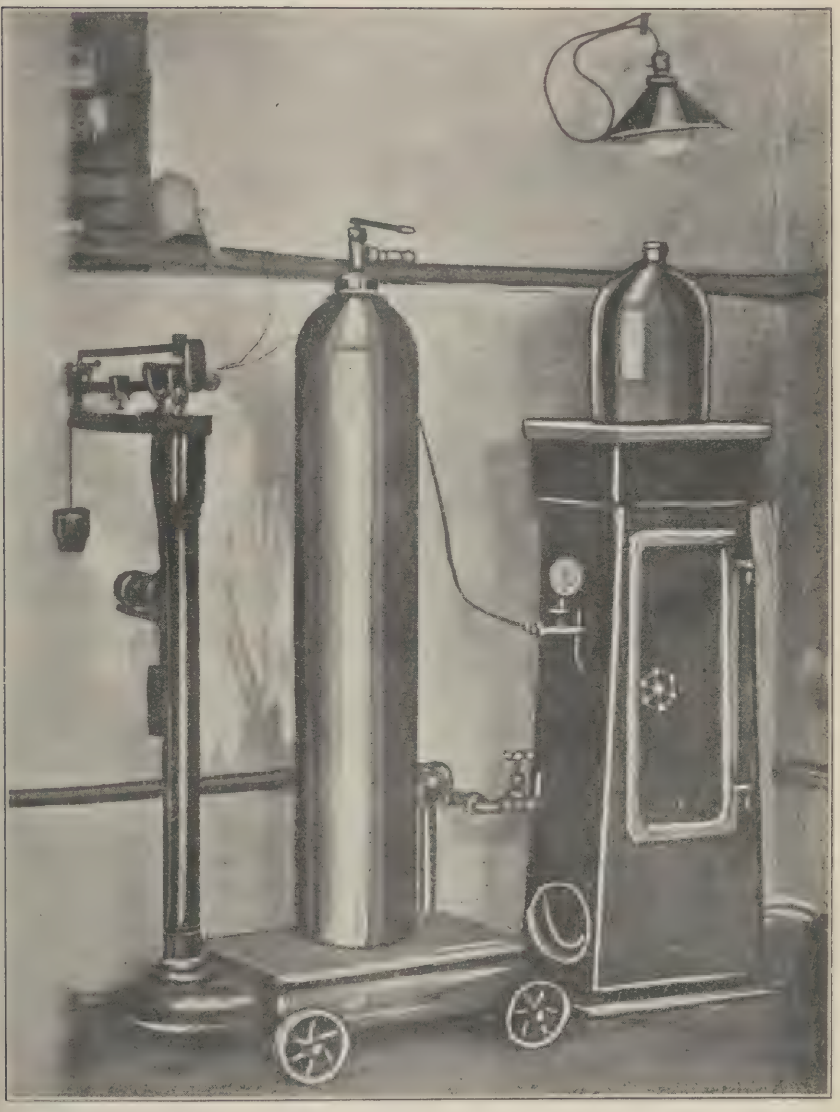


FIG. No. 209. Apparatus for the application of liquid chlorine in the treatment of sewage.

temporary chlorinating apparatus for the application of calcium hypochlorite may be constructed of barrels or tanks (page 293).

Quantity of chlorine required. The presence of not less than from 0.2 to 0.5 parts per million of residual chlorine in the sewage after a 15-minute contact period is indicative of effective disinfection. The amount of chlorine which must be added to the sewage, so that after contact for 15 minutes the requisite quantity of residual chlorine will be present, varies with the character of the sewage. The chlorine demand increases with the biochemical oxygen demand so that more chlorine will be required to produce residual chlorine in an effluent having a high oxygen demand, such as that produced by septic tank treatment, than in the effluent from an Imhoff tank or trickling filter (page 608). The chlorine demand of the effluent from any given plant varies with the efficiency of the plant in decreasing the oxygen demand of the sewage and is also influenced by the weather, and by variations in the quantity and quality of the raw sewage. Consequently, the quantity of chlorine which must be used to disinfect the effluent from any plant can be determined only by frequent tests for residual chlorine. The orthotolidine test is used for this purpose (page 313).

The quantity of chlorine required for septic tank effluent usually ranges from 10 to 25 parts per million, for Imhoff tank effluent from 5 to 20 parts per million, and for trickling filter effluent from 3 to 15 parts per million.

Application of chlorine. When chlorine is employed solely for the purpose of destroying pathogenic organisms, the chlorine solution is usually applied to the tank or filter effluent in the outlet conduit or pipe of the tank or filter. The sewage should be in contact with the chlorine for at least 15 minutes before it escapes from the outlet. If the outlet pipe is of such length that more than 15 minutes are required for the sewage to flow from the tank or filter to the outlet, no special arrangements for detaining the sewage are necessary. Otherwise, a contact or disinfecting tank must be installed. The size of the disinfecting tank is such that a detention period of 15 minutes or longer is provided. It is usually equipped with baffles to assure uniformity of flow and thorough mixing of the chlorine with the sewage. If the effluent from a trick-

ling filter is settled in a secondary sedimentation tank, this tank will also serve as a contact tank.

Prechlorination is the application of chlorine to sewage prior to other treatment by biological processes, such as septic or Imhoff tank treatment or filtration. Prechlorination is usually employed to facilitate other treatment measures and to control nuisances. Chlorine is applied in this manner to control odors (*supra* and page 634) and to control foaming in the gas vents of an Imhoff tank (page 642). Prechlorination greatly reduces the number of, or destroys, the pathogenic bacteria, particularly if the chlorine is added to the tank influent in quantities which will leave residual chlorine in the effluent.

The chlorine demand of fresh sewage is much less than that of stale or septic sewage, due mainly to the absence of, or to the comparatively small amount of hydrogen sulphide present in fresh sewage. Hydrogen sulphide is formed during septic decomposition and will absorb and render non-available large quantities of chlorine. Therefore, under certain conditions less chlorine will be required to disinfect the sewage by prechlorination than by the application of the chlorine to a septic effluent. This point can be determined for a given plant only by experimentation and comparative studies. Prechlorination does not prevent the ultimate septic decomposition of solids retained in the tanks, nor the oxidation of the organic matter in trickling filters, contact beds, or sand filters.

In the prechlorination of sewage, the chlorine solution is usually added to the sewage as it enters the treatment tank or in the dosing chamber of a trickling filter, contact bed or sand filter. Occasionally, it may be feasible to apply the chlorine to the sewage in an outfall sewer, sump or suction well, at some distance from and before it reaches the tank, in order to obviate or reduce septic action in the sewer.

SANITARY SURVEYS AND INSPECTIONS

A sanitary survey, or sanitary inspection, of a sewage disposal system is an investigation or study of such system with a view to determining the existence of defects in construction or operation. The conditions sought are those which are actual

or potential causes of nuisances or which are, or might become, factors in the transmission of pathogenic organisms by water or food. In the sanitary survey of existing sewage disposal facilities, the plumbing system, the sewerage system, treatment works or the conditions under which final disposal is accomplished may all be included in one survey, or each may be investigated separately. A sanitary survey relative to proposed sewage disposal systems includes inspection of the site and studies of the plans to determine if factors inimical to health or which would produce nuisances will be present when the system in question is placed in operation.

Sanitary survey and inspection of existing sewage disposal systems. Before beginning the actual survey of the different installations and facilities, the inspector should obtain from records and operating reports certain basic data, such as the volume of flow; the hourly, daily, and monthly variations in the flow; the quality of the sewage, including the presence of industrial wastes and storm water, and the water consumption rates. The plans of the sewer system should also be studied.

Plumbing systems (page 598). As one function of plumbing is to collect the wastes and transport them to the sewer systems so as to prevent the dissemination within the building of disease producing organisms, any defect which interferes with this function is of sanitary significance.

A thorough survey should determine if conditions are present which permit the escape of air or fluids from the pipes or fixtures into the interior of the building; if all fixtures are properly trapped; if waste and soil pipes are vented; if all connections are air and water tight; if the size and fall of the house drain is sufficient to prevent deposits, and if measures are taken to prevent material which would cause stoppage from entering the pipes.

Sewerage systems (page 600). The sanitary defects in sewers are primarily those which result in leakage of the sewage from the sewers. The sanitary survey should determine if leaks occur at points where sewage might contaminate water supplies or create nuisances, and the cause of such leakage. The sewage may escape through breaks in the pipes into the surrounding earth or onto the surface of the ground. Clogging caused by deposits may

result in flooded manholes from which the sewage flows over the surface of the ground or back-flows into the basements or cellars.

A sanitary survey for the detection and the prevention of leakage should consider the facilities for flushing the lateral sewers, if flushing is required, the size and fall of the sewers in relation to the quantity of sewage during periods of maximum flow, and factors which might cause breakage, such as poor construction or damage by traffic.

Sewage treatment works. The screens should be inspected to see if they are properly cleaned at intervals which will prevent the comminution and passage through the screen of the retained solids. The method utilized in the disposal of the screenings should be investigated for conditions of sanitary importance (page 613).

Grit chambers (page 619). The efficiency of a grit chamber in the removal of mineral substances from the sewage is dependent on the velocity of the flow through the chamber. If the chamber is too small for the quantity of sewage being treated or if the capacity has been unduly reduced by accumulated deposits, the velocity of the flow will be sufficient to prevent sedimentation of the mineral solids. If the chamber is too large for the quantity of sewage flowing through it, the velocity of the flow will be reduced to a point where the suspended organic substances will settle out and produce septic conditions in the grit chamber. The sanitary survey should, therefore, consider the construction and operation of the grit chamber in relation to the velocity of the flow and the efficiency of the chamber in the removal of mineral substances from the sewage.

Septic tanks (page 628). The functions of a septic tank are to remove part of the settleable solids from the sewage by sedimentation, and to reduce the volume of the retained solids by septic decomposition. Failure to accomplish this function efficiently is usually caused by too rapid flow of the sewage through the tank, by turbulence of the sewage in the tank, or by short circuiting currents. An inadequate detention period is due to the tank being primarily too small or to a decrease in capacity caused by the accumulation of sludge. Turbulence of the liquid in the tank or cross or vertical currents may be caused by uneven operation, or improperly placed baffles, inlets or outlets.

The sanitary survey should include a study of the efficiency of the tank in the removal of settleable solids and determine the cause of any failure to do so. The walls, baffles, and influent and effluent channels should be inspected for deposits which would produce nuisances.

Plain sedimentation tanks. The plain sedimentation tank is designed to remove a portion of the settleable solids by sedimentation without permitting septic decomposition to occur in the tank. The sanitary survey should, therefore, consider particularly the detention period and the methods employed in removing the sludge. The biochemical oxygen demand and stability of the effluent and the proportion of settleable solids removed by the tank are indicative of the efficiency of the tank and should be determined by suitable tests (page 711). As in the case of the septic tank, the walls, baffles and the influent and effluent channels should be inspected for deposits of organic matter which might produce nuisances.

Imhoff tanks (page 635). A properly operated Imhoff tank should produce thoroughly decomposed sludge and an effluent having a comparatively low biochemical oxygen demand. The sanitary survey of an Imhoff tank installation should consider the oxygen demand and the stability of the effluent (page 710); the proportion of settleable solids retained in the tank; the ebullition of gas in the flow chamber; the presence of scum in the flow chamber; the depth of the sludge below the slot, and the presence of deposits on the sides of the V-shaped flow chamber bottom. The nature of the sludge in the sludge chamber should be determined by examination of a sample withdrawn through the sludge pipe. Operating data relative to the length of the detention period, the intervals at which the flow is reversed, and methods used, if any, to control foaming should also be considered.

Removal and disposal of sludge. All tanks employed in the treatment of sewage produce sludge, the characteristics of which depend on the type of tank concerned. The methods employed to remove the sludge from the tank influence the quality of the effluent and are, therefore, important in the operation of the plant. The sanitary survey should consider the methods and appliances used in the removal of the sludge; the intervals at which the sludge is removed, and the nature

and effectiveness of the facilities for drying, pressing or otherwise dewatering and preparing the sludge for final disposal (page 662).

Trickling filters, contact beds and sand filters. The effectiveness of properly constructed trickling filters, contact beds, or sand filters depends principally on the efficiency of their operation. The sanitary survey therefore consists mainly of an investigation of such features of operation as the methods of dosing, the thoroughness of drainage, the length of the resting period, and ventilation. The existence and causes of clogging, and the cleaning methods employed should also be considered. The determination of the biochemical oxygen demand and the stability of the effluent is an essential part of the sanitary survey of these installations.

Secondary sedimentation tanks. The sanitary survey of secondary sedimentation tanks is conducted in much the same manner as the survey of plain sedimentation tanks (*supra*).

Activated sludge plants. The efficiency of a properly constructed activated sludge plant in the production of a clarified effluent depends on skilful operation, and a sanitary survey of such a plant is concerned largely with the operating features (page 651). The subordinate phases of the process such as activation of the sludge, aeration, sedimentation, or the removal and return of the sludge are interdependent so that defects developing in any one stage will produce serious operating difficulties in some or all of the others. Consequently, each of these phases should be carefully studied during the conduct of a sanitary survey.

Chlorination plants. The efficient operation of a sewage chlorinating plant depends on the proper application of chlorine in quantities sufficient to produce the desired results. The sanitary survey should include a study of the procedures employed in the application of the chlorine; the thoroughness with which the chlorination is supervised and, where pertinent, the amounts of residual chlorine maintained in the effluent.

Diluting water (page 605). The production of nuisances in the stream, lake, or other body of water receiving the discharge from an outfall sewer, or the outlet pipe of a sewage treatment works, is usually a measure of the efficiency of the sewage disposal methods employed. A sanitary survey should include observations relative to the presence of sludge deposits, odors,

ebullition of gas, scum on the surface, or other evidence of damage to the water by the sewage. The extent to which the water is contaminated with disease producing organisms should be estimated, where such studies are indicated, by laboratory examinations of the water for the presence of organisms of the coliform group. Sometimes two or more sewage disposal systems discharge into the same body of water so that all of the abnormal conditions noted may not be caused by the sewage from the system being inspected. If the outlet is in a stream, comparative studies with reference to these conditions should be made of the water above and below the outlet. If the sewage is discharged into a lake, the condition of the water near the outlet should be compared with that in a part of the lake not reached by the sewage from the outlet in question. Where the diluting water is, or appears to be, grossly polluted, it may be desirable to determine the biochemical oxygen demand of the water before and after it receives the sewage. In the case of small streams, where the volume of water available for dilution of sewage is, or may become insufficient, the volume of the flow should be determined.

Sanitary survey of proposed sewage disposal systems. A sanitary survey of a proposed sewage disposal system involves a study of the plans of the sewage system with regard to arrangement and location of the sewers, sewer grades, design of the sewers, and capacity of the sewers in relation to the expected volume of sewage. A study of the proposed method of treating the sewage should be made with a view to determining if it will meet the requirements of the local situation. Where necessary and practicable, the experience of nearby communities in the disposal of sewage should be investigated in order to obtain data pertaining to the effect of local conditions on the operation of sewage disposal systems.

The characteristics of the diluting water, that is, the volume, rate of flow, variations in flow, depth, or currents, should be investigated to determine if the diluting water available will satisfactorily dispose of the effluent from the proposed system. If the diluting water in question is used to dispose of sewage from other communities, the existence of nuisances due to such sewage and the effect which it has on the quality of the water should be ascertained by inspection and laboratory analysis.

LABORATORY ANALYSIS

Chemical analyses are made of sewage and sewage effluents to determine the efficiency of sewage treatment procedures in the removal of nuisances or the feasibility of utilizing a certain body of water for the dilution of a given sewage or sewage effluent. Usually, the information sought by chemical tests is that pertaining to the stability and the suspended and settleable solids content of the sewage.

Laboratory analyses of sewage are made in Medical Department laboratories, except the relative stability and settleable solids tests which can and should be made at the station or camp where the sample is collected.

Bacteriological examinations of sewage effluents, or of the diluting water into which sewage is discharged, may be made to determine the efficiency of treatment procedures, particularly disinfection, in the elimination of organisms of the coliform group.

Collection of samples. As the composition of sewage varies at different times of the day, a composite sample should be taken. This is usually done by collecting from 100 to 200 c.c. every hour for 24 hours and mixing the hourly samples together to form one composite sample. The mixing may be done at the time of collection or at the end of the sampling period. The complete sample should have a volume of at least two liters.

Wide-mouthed, glass stoppered bottles of 100 to 200 c.c. capacity and equipped with wire handles should be used for the collection of samples. The bottle should be completely filled so that all samples are alike in volume.

The sample may be composited in volumes proportionate to the flow at the time the different samples are collected. Usually, however, constant volume samples are sufficiently accurate for practical purposes.

Where experience or testing shows that the sewage is of average strength at a certain time each day, one sample may be collected at that time and considered as representing a composite sample. This method eliminates the labor required for the collection of a composite sample, but can be used only where the composition of the sewage is fairly constant from day to day.

Preservation of samples. The hourly samples should be placed on ice as soon as collected. Samples that are to be transported to a laboratory for analysis, or where the analysis cannot be made within six hours, should be preserved with chloroform, sulphuric acid or formaldehyde. Six c.c. of chloroform, or from one to four c.c. of concentrated sulphuric acid or formaldehyde, the exact amount depending on the strength of the sewage, is added to each liter of the sample. A sample containing a preservative cannot be tested for relative stability or biochemical oxygen demand. Samples to be used for these tests should be kept on ice or the analysis should be started within six hours after collection.

Transportation of samples. Samples for chemical analysis which are to be forwarded to a laboratory should be placed in one-liter or two-liter bottles. The bottles should be so filled that there is no air space between the surface of the liquid and the stopper. If the samples are to be sent by express, the bottles must be securely packed. Samples for bacteriological analysis are prepared for transportation and forwarded as described on page 362.

Tests for relative stability and settleable solids. The relative stability and settleable solids tests will furnish a great deal of information of practical value in the operation of sewage treatment works. Either of these tests can be performed locally without the aid of elaborate laboratory equipment.

Relative stability test. The relative stability test is used to determine the stability of sewage effluents. The results are expressed as the percentage which the oxygen available in the sewage is of the total quantity of oxygen required to satisfy the biochemical oxygen demand and stabilize the sewage. The test is performed as follows:

A methylene blue solution is prepared by dissolving 0.5 gram of methylene blue in one liter of water.

Samples of the sewage are placed in glass stoppered bottles of approximately 150 c.c. capacity. The bottles should be completely filled.

A water seal is attached and the temperature of the sample brought to 20°C. Then exactly 0.4 c.c. of the methylene blue solution is added below the surface of the liquid. The sample is incubated at from 18°C. to 22°C. until the blue color disappears. If no incubator is available, the sample may be allowed to stand at room temperature.

The time required for the blue color to disappear at a temperature of 20°C. indicates roughly the percentage which the available oxygen present is of the amount required to satisfy the biochemical oxygen demand of the sewage, as follows:

RELATIVE STABILITY

Time required for decolorization at 20°C.	Relative stability	Time required for decolorization at 20°C.	Relative stability
Days	*Percentage*	*Days*	*Percentage*
0.5	11	8.0	84
1.0	21	9.0	87
1.5	30	10.0	90
2.0	37	11.0	92
2.5	44	12.0	94
3.0	50	13.0	95
4.0	60	14.0	96
5.0	68	16.0	97
6.0	75	18.0	98
7.0	80	20.0	99

The relative stability test is only roughly quantitative. As a rule, if the effluent is 68 per cent stable, that is, if it is not decolorized in less than 5 days, it can be disposed of without serious nuisance under ordinary conditions. If it is 90 per cent stable it can be disposed of by dilution without nuisance in practically any water. As a means of comparing roughly the results of the relative stability test with those obtained by analysis for biochemical oxygen demand, it may be considered that where an effluent is decolorized in less than 5 days the biochemical oxygen demand is more than 50 parts per million and if the color remains until the tenth day of incubation, the biochemical oxygen demand is less than 30 parts per million.

Settleable solids test. Ordinarily, no settleable solids are demonstrable in the effluent from a well operated sewage treatment tank. The test is of value, however, in determining the strength of raw sewage, or in determining the efficiency of tanks in the removal of the settleable solids. The settleable solids test is also used to ascertain the volume of activated sludge in the sewage at different stages of the activated sludge process.

One liter of the sewage to be tested is placed in an Imhoff cone (a conical glass having a capacity of 1000 c.c. and gradu-

ated to 40 c.c.), or a 1000 c.c. graduated cylinder, and allowed to stand for two hours. The glass should be rotated every 15 minutes to detach the settleable solids which adhere to the sides. At the end of the two-hour period, the volume of settled solids is read to the nearest one-tenth c.c.

SMALL SEWAGE DISPOSAL SYSTEMS

The sewage from isolated buildings, or groups of buildings, having a piped water supply but no connection with a general sewer system may be disposed of, either prior or subsequent to some form of treatment, by discharge into a nearby stream, or on the surface of the ground at some isolated spot. Usually, the sewage must be treated prior to ultimate disposal. A typical treatment installation consists of a grease trap, a small septic tank with a siphon and siphon chamber, distributing box, and a tile field in which the effluent is disposed of by subsurface irrigation.

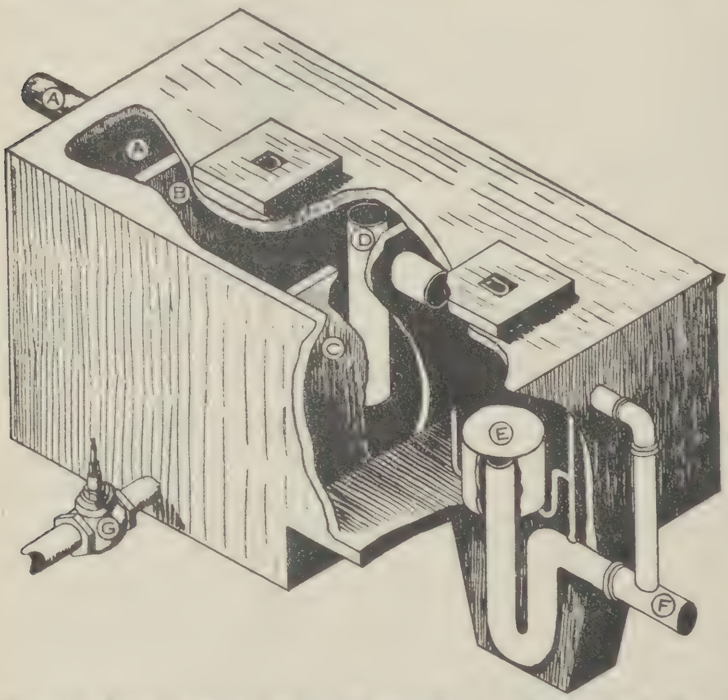


FIG. No. 210. Small septic tank (Schematic). A—Inlet. B—Baffle board. C—Siphon chamber. D—T-shaped tile outlet pipe. E—Siphon. F—Outlet pipe. G—Sludge drainage pipe.

The small septic tank (Fig. No. 210). The most common method and, if the effluent can be safely disposed of, the most satisfactory method of treating sewage where a sewer system is not accessible, is by means of a small septic tank.

The principles underlying the construction and operation of a small septic tank are the same as for a large installation (page 628). The capacity of the tank should be not less than 30 gallons per person for barracks or comparable buildings, depots, shops, or offices, and not less than 50 gallons per person for officers' and married enlisted men's quarters, and for hospitals. In order to compensate for the uneven flow through small tanks, the tank usually has a capacity equal to about a 24 hour flow of sewage, and therefore a detention period of 24 hours. A 500 gallon tank should be installed for 10 persons and a 2500 gallon tank for 50 persons. The minimum size for any one tank should be not less than 50 cubic feet.

Construction of the tank (Fig. No. 210). The tank is usually rectangular in shape, although cylindrical tanks are sometimes used. The depth should be not less than 36 inches below the flow line, with not less than 12 inches of free board above the flow line. The width, in rectangular tanks, should be approximately one-half of the length. The inlets and outlets vary in design in the different types of tanks. Ordinarily, the inlet and outlet pipes curve downward and terminate at about mid-depth of the tank. Instead of curving downward they may be guarded by scum boards placed a few inches in front of the inlet and behind the outlet. The tank may have one or more hanging baffles which extend about 18 inches below the surface. The baffles may also serve as scum boards by extending six to eight inches above the flow line.

The tank is usually made of concrete, with the walls about six to ten inches in thickness. It is usually covered and provided with a capped vent pipe and, in the larger tanks, with a manhole. The cover may be of plank or concrete.

A clean-out drain should be provided. This drain usually consists of a 4-inch cast iron pipe and passes through the wall of the tank near the bottom. It is equipped with a gate valve just outside the tank. The valve stem passes up to a brick, concrete or tile valve box at the surface of the ground. The

drain may be connected with a 6-inch tile pipe through which the sludge flows to the place of disposal.

Location of the tank. The tank is, as a rule, placed underground with the top level with or slightly below the surface of the ground. It must be accessible for inspection and cleaning. If possible, the tank should be so placed that sufficient fall can be secured for drainage of the sludge by gravity through the cleanout drain.

The tank should be placed as far away from an inhabited building as practicable, and never within 100 feet of a spring or well.

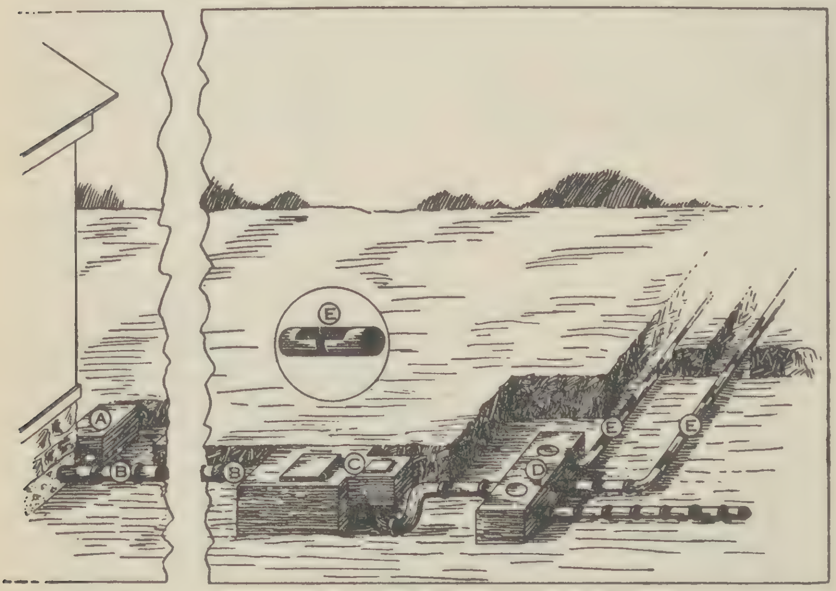


FIG. No. 211. Typical small septic tank installation (Schematic). A—Grease trap. B—House sewer. C—Septic tank. D—Distribution box. E—Tile lines showing method of protecting space between tiles.

Sewer from building to tank (Fig. No. 211). The drain pipe of the building and the inlet of the tank are connected by means of a house sewer of 4 or 6-inch vitrified clay sewer pipe. The house sewer should be laid, if practicable, in a straight line from the house to the tank. A manhole should be installed if it is necessary to make a bend of as much as 45 degrees. The house sewer should be laid, where practicable,

on a grade of at least three per cent. The joints should be made tight with cement mortar and the roots of trees and shrubs should be avoided.

The grease trap. Grease and soap from kitchens and baths will interfere with the operation of a septic tank and purification field, and should be removed from the sewage by a grease trap. The kitchen and bath wastes are drained through a grease trap and a separate waste pipe into the house sewer beyond the connection of the sewer with the drain pipe so that no wastes from toilets will pass through the grease trap (Fig. No. 211).

Disposal of the effluent. The tank effluent is usually disposed of in tile fields by subsurface irrigation, especially in the case of the smaller installations. In other instances, the effluent may be further stabilized by oxidation in a trickling filter and disposed of by dilution in water, or the tank effluent may be disposed of directly by dilution.

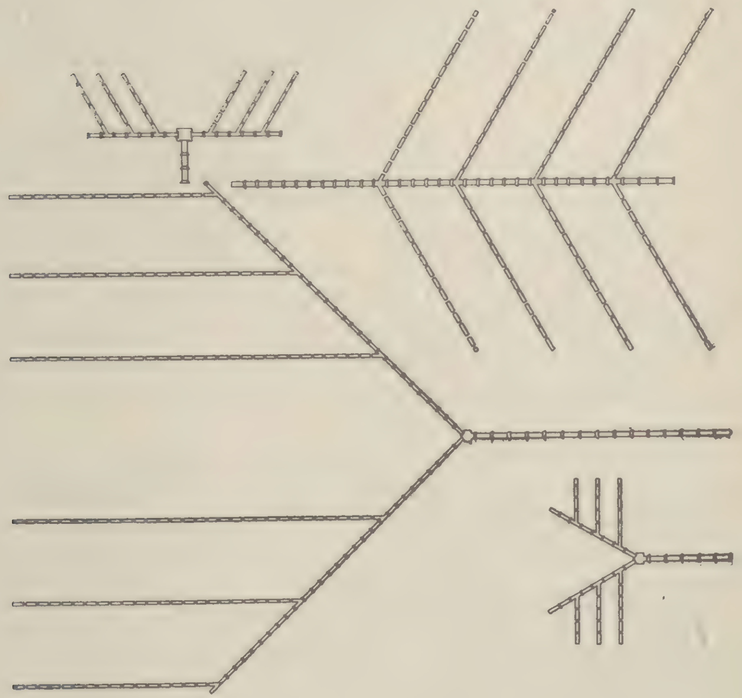


FIG. No. 212. Tile or purification field showing different methods of arranging tile lines.

Tile fields (Fig. No. 212). A tile field consists of lines of open joint tile. The tiles are usually laid from 12 to 20 inches below the surface of the ground. There may be a single line of tile or a main line with a number of lateral lines. Two or more separate tile fields may be employed in the larger installations.

As a rule, farm tile four inches in diameter is used. Larger or smaller sizes may be used, depending on the ratio between the amount of sewage received at each dose and the total length of the drains.

The tiles are laid with a fall of from two to six inches in 100 feet, and with the ends of the sections separated by about one-fourth inch. The trenches are one foot in width and the tiles are placed on top of a layer of gravel, cinders, or other porous material from 6 to 12 inches thick. The material need not be placed around or above the tile, but a piece of tar paper or burlap, or a half collar of pipe should be laid over the top and sides of the opening between the ends of tiles to exclude earth. The trench is backfilled with earth. If more than one tile line is constructed, the lines should be not less than six feet apart.

In order to prevent sagging of the tile line or breakage, it may be necessary to provide a support for the tile. A board support can be made by driving stakes of suitable length in the bottom of the trench about 10 or 12 feet apart and nailing one by four inch boards to the side of the stakes so that the upper edge will form a base for the tile. The board and stakes are then surrounded with gravel or other filling material and the tile centered so that it rests directly on the upper edge of the board and is held in place by the gravel, cinders or earth packed around it (Fig. No. 213).

The length of tile line required for any installation is governed by the ability of the ground to absorb fluids, as determined by the character of the soil and the amount of rainfall. About 20 feet in loose sand and gravel, from 25 to 50 feet in loam, or in loam and sand, and about 100 feet in clay and gravel or clay and loam soils should be provided as a minimum for each person. This method cannot be used successfully in tight clay soils or hard pan. All tile lines should be so constructed that they can be lengthened if necessary.

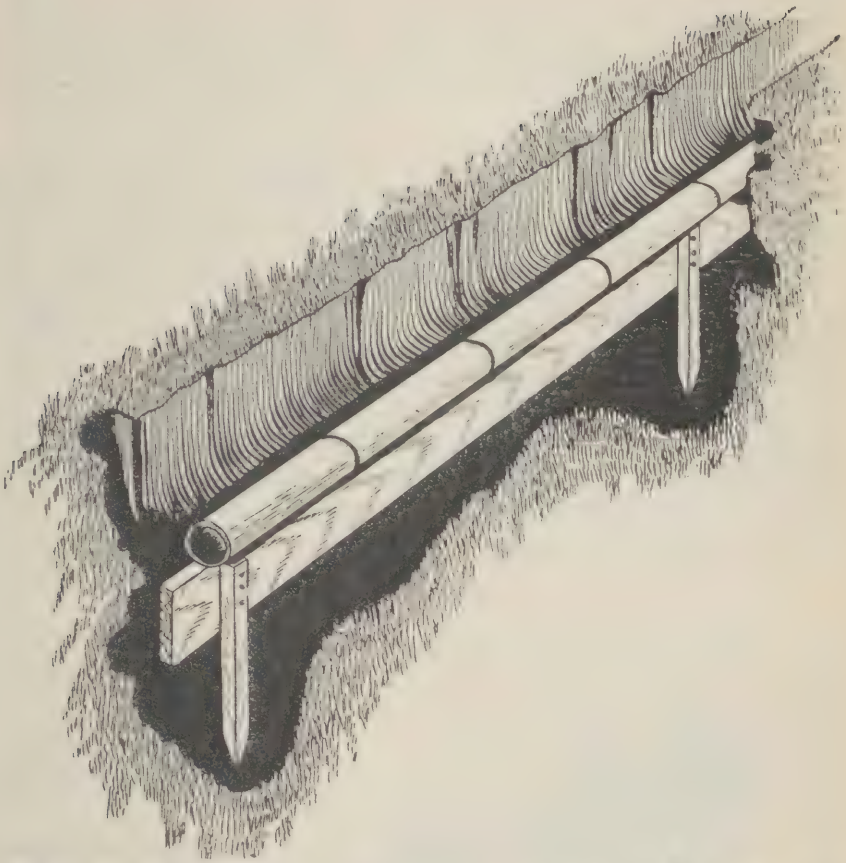


FIG. No. 213. Showing method of supporting tile to prevent settling of tile line. The trench has not been back-filled and the upper surfaces of the tile joints have not been covered.

The tile line or field should be at least 100 feet from the nearest well or spring.

Application of sewage to the tile fields. The tank is connected with the tile field or distribution box by a 4-inch sewer of bell and spigot pipe with tight joints. The fall should be at least five inches per 100 feet. If a siphon is used, the fall between the tank and the tile field should be at least 2.5 feet.

Siphon and siphon chamber. All tanks, particularly those of more than 500 gallons capacity, should be equipped with a siphon and siphon chamber (page 678). The effluent from the smaller tanks may be allowed to overflow directly into the sewer

leading to the tile field. However, when this is done, the liquid tends to pass out of the tiles in the upper part of the line and, if there is any considerable amount to be disposed of, the soil in the vicinity of the first few tiles will soon become clogged or water logged.

When the tile field is dosed by means of a siphon, a sufficient quantity of the effluent is discharged at one time to insure that all of the tile lines receive sewage throughout their entire length. In the interval between discharges the sewage seeps out of the tiles and is absorbed into the soil. Usually, the capacity of the siphon chamber is about one-fifth of that of the septic tank, and should not be more than 75 per cent of the capacity of the tiles that are to receive the dose.

Distribution box (Fig. No. 214). The distribution box is a small tank set in the sewer leading from the tank to the tile field and serves to equalize the flow of sewage to the different tile lines. The outlet sewer of the tank carries the sewage into

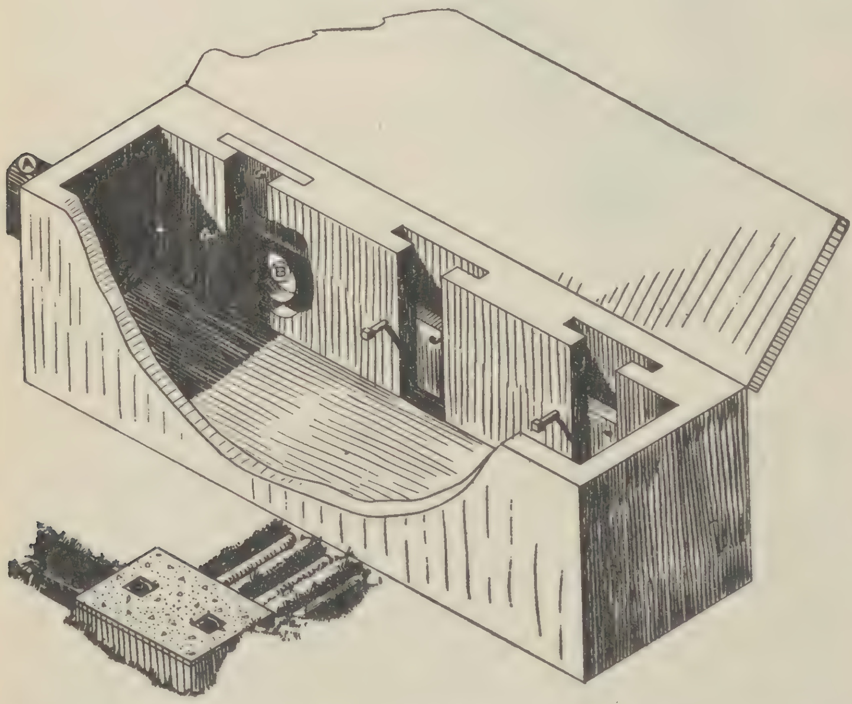


FIG. No. 214. Distribution box (Schematic). A—Inlet sewer from septic tank. B—Outlets to tile fields, showing stop boards.

the distribution box and there is an outlet from the box for each tile line. If there is more than one tile field, each field has a secondary distribution box which receives sewage from an outlet in a main distribution box. The distribution box is usually about 20 inches deep and one foot wide. The length is governed by the number of outlets. The outlet pipes should be on the same level at or near the bottom of the box. The sewer should enter not more than two inches above the bottom of the box. The distribution box can also be used as a diversion chamber by controlling the flow of liquid into the outlets by means of stop-boards which fit against the ends of the outlet pipes. By adjusting the stop-boards, one tile field, or a part of a field, can be utilized while the other fields or lines are resting.

The drains from the distribution box to the tile lines consist of 4-inch bell and spigot pipe laid with cemented joints.

Care and operation. No rags, rubbish, or sticks should be allowed to enter the disposal system, as such material does not disintegrate in the tank and frequently causes stoppage in the pipes or tiles.

The tank should be cleaned whenever the sludge and scum occupy as much as 25 per cent of the depth of the tank. If the tank has a clean-out drain, the sludge is allowed to flow through the drain pipe to a shallow pit which is then covered with boards and earth. In the absence of a clean-out drain the sludge and the overlying fluid must be dipped or pumped out and hauled or carried away to the pit. Normally, the tank will require cleaning at intervals of from six months to several years.

The tank should be inspected at monthly intervals and the depth of sludge ascertained. If the scum becomes thick enough to reach the top of the septic tank or the cover, or to interfere with the escape of gases, it may be broken up with a pole so that some of it will sink to the bottom.

The grease trap should be inspected and the grease and debris cleaned out at intervals of not longer than one month.

Should the soil around any tile line show evidence of overdosage, as indicated by odors, water soaked earth, or pooling of the fluid on the surface, the flow to that line should be shut off at the distribution box by a stop-board or plug and the soil permitted to rest until it is again in good condition.

Trickling filter, contact bed, and intermittent sand filter. In instances where the area, or the proper type of soil, is not available for a tile field, or where climatic conditions are such that a tile field cannot be successfully operated, the effluent from a small septic tank may be further stabilized by passage through either a trickling filter, contact bed, or intermittent sand filter, and disposed of by dilution or broad irrigation (pages 605 and 610).

The construction and operation features of trickling filters, contact beds or intermittent sand filters for small plants are the same as those described for the larger installations, due allowance being made for differences in size and capacity (page 669).

Small Imhoff tanks. A small Imhoff tank, instead of a septic tank, may be installed to treat the sewage from buildings having a piped water supply but no sewer connections. The principles involved in the construction and operation of a small Imhoff tank are the same as those for the larger tanks (page 635). The design detention period in the flow chamber should be not less than six hours, and preferably longer, in order to compensate for the variations in flow. The sludge chamber should have a capacity of about four cubic feet per person served. The horizontal area of the gas vent should be not less than 25 per cent of the tank area. The tanks vary from 8 to 15 feet in depth.

The effluent from an Imhoff tank is disposed of in the same manner as that produced by the septic tank.

Operation of an Imhoff tank. The same precautions must be taken to prevent rubbish from entering an Imhoff tank as in the case of the septic tank. The sides of the flow chamber and the scum boards should be kept free from deposited material. The sludge is removed through a sludge pipe (page 639) by hydrostatic pressure or pumping, and disposed of in a pit or on a sludge drying bed (page 662). The sludge should not be permitted to accumulate to within less than six inches of the slot.

Because of the difficulties inherent in the operation of an Imhoff tank, which, in the case of small tanks, are accentuated by the fluctuations in flow, a small Imhoff tank is usually less satisfactory than a small septic tank.

CHAPTER XV.

DISPOSAL OF HUMAN WASTES IN TEMPORARY CAMPS AND BIVOUACS

Under the conditions which usually prevail in temporary camps or bivouacs, where no water carriage system of sewage disposal is available, it becomes necessary to dispose of feces and urine directly in the earth, either in pit or trench latrines or by burial subsequent to collection in pail latrines. Under very exceptional circumstances, when recourse can be had to no other method, the feces may be disposed of by incineration.

The purposes of latrine disposal are to prevent the excreta being transferred to the food or drinking water of the troops by flies or on the hands or clothing of individuals, to control fly breeding in the fecal material, and to obviate nuisances due to offensive odors or unsightly accumulations. Earth disposal in latrines is not undertaken with a view to stabilization of the organic matter. The nitrifying bacteria normally in the soil are not present at depths of more than 18 to 24 inches below the surface. In pit latrines, and usually in trench latrines also, the excreta is buried below this limit so that the only organisms concerned in the decomposition of the organic matter are those derived from the intestinal tract. The liquid portion drains away into the soil and the solid material slowly disintegrates and decomposes into stable compounds, the whole process requiring several months to a year or more for completion.

Latrines are company installations. They are usually located within the company area and are constructed and maintained by the personnel of the company concerned.

Latrine space for troops. A sufficient number of latrine seat spaces should be provided to accommodate from five to ten per cent of the command at one time, at the rate of two

lineal feet of latrine per space. Usually, where practicable, eight spaces, or 16 lineal feet, are provided for each 100 men.

Types of latrines. Certain kinds of latrines have been found by experience to be best suited for use in military camps, but these basic types are susceptible of many modifications in construction and in methods of preventing nuisances and maintaining sanitary conditions. The general principles of construction and maintenance of latrines are discussed below, but variations in construction and methods of maintenance must be determined by local conditions and requirements, and by the ingenuity of those responsible for these installations.

Trench latrines are installed for troops in bivouac or in camps of not more than two or three days duration. Pit latrines are employed whenever the troops will remain in camp for a week or longer. Pail latrines may be used in permanent or semi-permanent camps where the character of the soil or lack of space prohibits the use of pit latrines. Pail latrines are frequently used in field and war time hospitals to obviate the exposure of convalescent patients to inclement weather and to facilitate the care of the sick.

The pit latrine. The pit latrine is an adaptation to military conditions of the ordinary earthen privy. It differs essentially from the earthen privy in that it is larger and will accommodate more persons at one time, and is a temporary expedient with no provision for removing the contents. The typical pit latrine consists of the pit, latrine box, urinal and latrine enclosure.

Construction of the pit. The pit is usually two feet in width. The depth varies from four to ten feet, depending on the level of the ground water table, the character of the soil, the presence or absence of a rock stratum, and the length of time that the latrine is to be used. If the excavation extends to below the ground water table, water will seep into the pit. When the ground water table is within a few feet of the surface, it should be avoided by the use of shallow pits.

A tight clay soil will interfere with the drainage of liquids out of the pit. Where the clay stratum lies at a depth of four feet or more the pits should be shallow so that the looser top soil may be utilized for drainage; if the clay extends to or nearly to the surface, then the pit can be employed only as a tank to store the excreta without elimination of liquids by drainage.

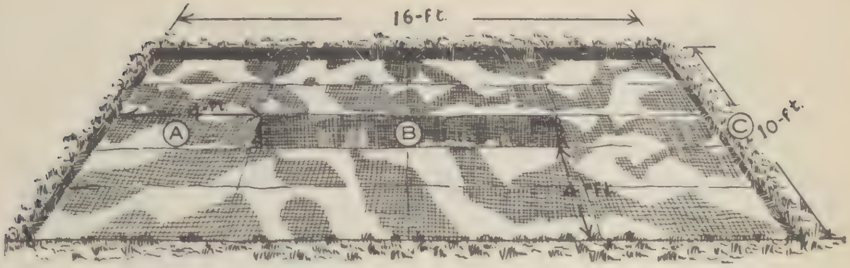


FIG. No. 215. Method of flyproofing latrine pit. A—Oil soaked burlap extending completely around pit. B—Opening of pit. C—Sidewall of excavation in which burlap is placed.

The pit cannot be dug in a hard rock stratum without the use of an explosive. If, however, the rock is broken with dynamite, drainage may be secured through the fissures produced in the rock by the explosion.

The length of the pit is governed by the number of spaces that are to be provided and the length of the standard latrine box. If latrine space is to be furnished for eight per cent of a company of 200 men, then thirty-two lineal feet of pit must be dug. As the standard quartermaster box is eight feet long, the length of individual latrine pits must be eight feet, or a multiple of eight feet, if the standard box is used.

If latrine space is provided for eight per cent of the organization, a pit four feet in depth should suffice for at least two weeks. For longer periods, one foot in depth should be added for each additional week. For example, where a pit is to be used for four weeks it should be six feet deep. If it is to be used for six weeks, it should be eight feet deep.

All of the dirt removed in excavating the pit should be placed at least six feet in the rear of the pit. A drainage ditch not less than six inches deep should be dug around the pit in such a way as to carry surface water away from the pit. If a latrine screen or other form of enclosure is used, the drainage ditch should be on the outside of the enclosure.

Flyproofing (page 786). The eggs of the house fly are deposited on the excreta in the pit and the larvae remain in the contents of the pit until maturity is reached. Just prior to pupation many larvae endeavor to migrate from the fecal mass in search of a dry place in which to pupate. Mature house fly larvae can penetrate through loose earth as far as four feet and the freshly

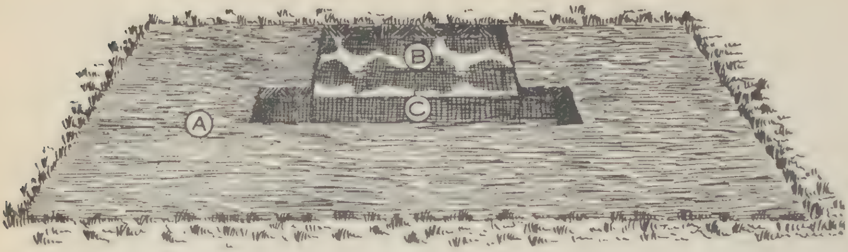


FIG. No. 216. Method of flyproofing latrine pit with oiled burlap. A—Layer of earth replaced and tamped down over burlap. B—Oiled burlap exposed before replacement of earth. C—Opening of pit.

emerged adult insect is also capable of penetrating loose earth for a distance of one foot or more.

The purpose of flyproofing a latrine pit is to prevent the larvae or the adult insect from reaching the surface of the ground around the pit, their escape through the mouth of the pit being controlled by the latrine box. Flyproofing of the pit is, therefore, necessary only when the pit is dug in loose earth, such as light loam, or sand and loam, as neither the larvae nor the adult insect can burrow through tight clay soil or rock.

In flyproofing the pit, an area four feet wide and completely surrounding the pit is excavated to a depth of six inches (Figures No. 215 and 216). The floor of this excavation is covered with burlap soaked in crude oil, the burlap being placed so that it hangs down into the pit to a depth of eighteen inches. The earth is then replaced over the burlap and tamped down. In the event that burlap is not obtainable, the earth removed from the excavated area should be mixed with crude oil and tamped back into place or, if crude oil is not available, the earth may be hardened by moistening with water and tamping.

Standard quartermaster latrine box. The standard quartermaster latrine box is made and issued by the Quartermaster Corps. The shape and dimensions of this box are as shown in Fig. No. 217. It is flyproof when new, but as the lids warp and the boards crack, openings are left which will permit the entrance and exit of house flies.

The knockdown latrine box (Fig. No. 218). The dimensions of a knockdown latrine box are the same as those of the standard quartermaster box. It is so constructed that

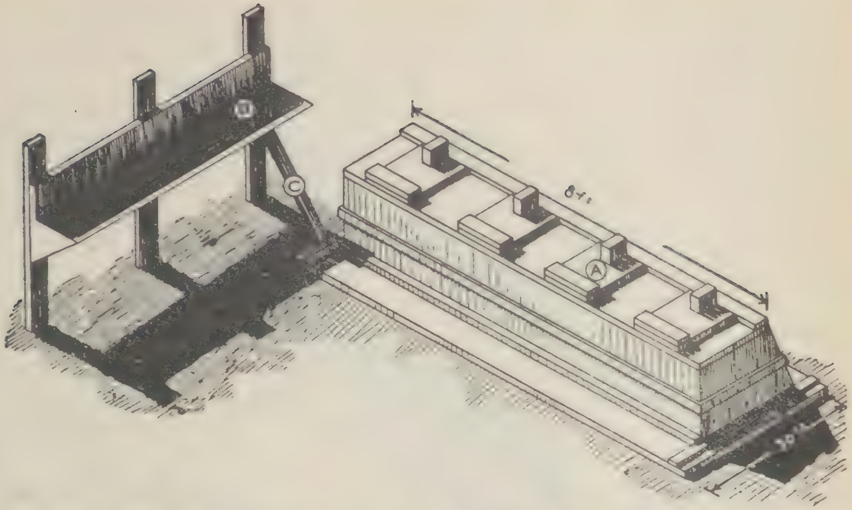


FIG. No. 217. A—Standard latrine box. B—Trough urinal. C—Pipe leading from urine trough into latrine pit.

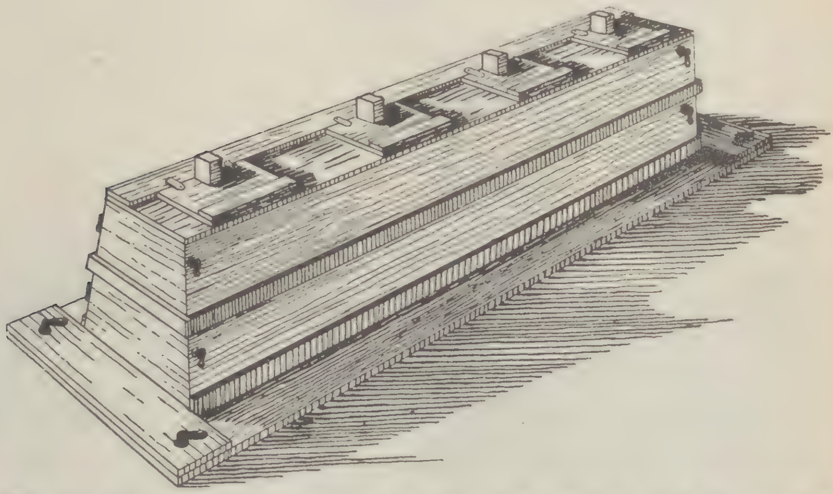


FIG. No. 218. Knockdown latrine box showing position of tail nuts and rods which permit the box to be taken apart.

the ends, top, sides and base are held in place with iron rods equipped with wing or tail nuts which permit the box to be taken apart and packed flat for transportation in a truck or freight car. The box can be dismantled or erected in five minutes by two men without the aid of tools (Fig. No. 219).

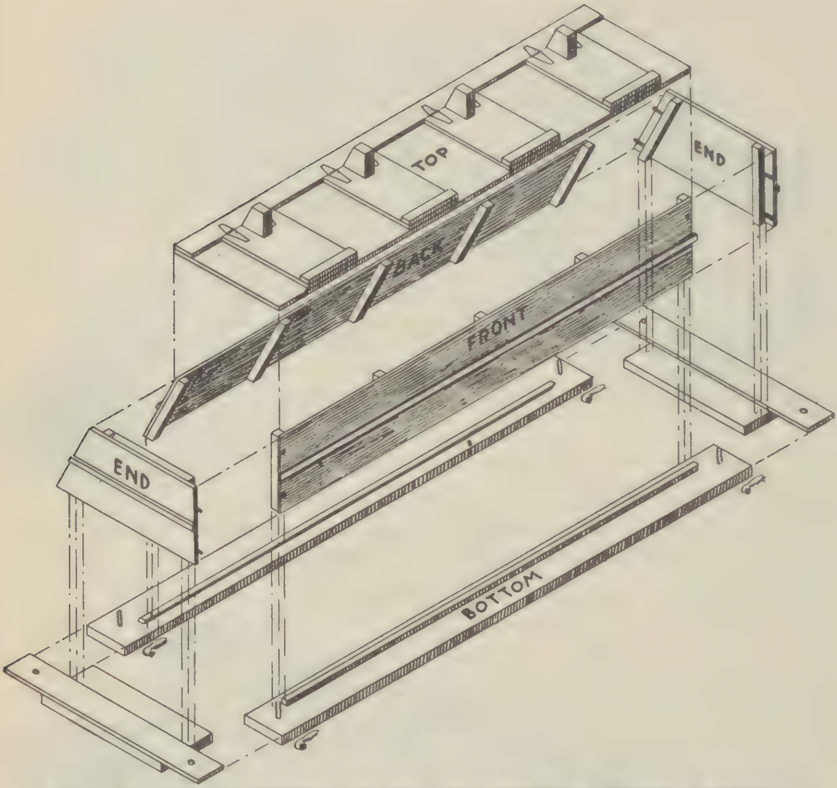


FIG. No. 219. Knockdown latrine box showing different sections.

Installation of latrine boxes. As the base of the standard latrine box is two and one-half feet wide, it can be placed over a two-foot pit so that there is an overlap of three inches on each side. Earth should be tamped around the base to prevent the entrance or exit of house flies. In the case of long pits, two or more of the boxes may be placed end to end, but care should be taken that the union between two boxes is made flyproof. This can be done by placing burlap over the crack between the boxes.

Improvised latrine seats. Improvised latrine seats may be constructed in various ways. Poles supported by cross pieces may be utilized for this purpose. Improvised seats of this character have the disadvantage that they do not protect the contents of the pit from flies. They can, however, be constructed from the materials usually available about a camp.

Other types of latrines. A great many variations in the ordinary latrine pit and standard latrine box have been devised. In some instances, ventilators or ventilating stacks have been used. In other instances, fly control and deodorizing have been accomplished by burning brush, oil or rubbish in the pit. Some such installations have a removable box and the pit is burned out from time to time by building a fire in it. Others have been equipped with metal boxes and a smoke stack at one end and a draft opening at the other. These can be burned out at frequent intervals without removing the box. In one type, inflammable rubbish, or brush, is placed on the bottom of a clean pit and the feces are allowed to accumulate on top of it. This material is then burned, usually with the aid of oil, at intervals of several days or longer, depending on the amount of feces deposited. Also, latrines have been made with fire grates of different kinds in the depths of the pit to facilitate burning of the fuel and the feces.

The walls and bottom of a pit may be made of concrete. A concrete pit can be cleaned out at intervals, or it will serve as a fire box for burning the feces.

Where the soil is very loose it may be necessary to reinforce and support the walls of the pit with boards or sand bags to prevent caving. If sand bags are used, the dimensions of the pit must be increased accordingly.

FIG. No. 220. One method of installing canvas latrine screen for a one box latrine.

The bored-hole latrine consists of a round hole in the ground 14 to 18 inches in diameter and from 15 to 20 feet, or more, in depth. The hole is made with an earth or clay auger or a post hole auger attached to a shaft of suitable length. In soft or sandy soil the hole may be lined with wooden strips or with metal drums from which the ends have been removed. The hole usually extends to below the ground water table so that the lower portion is filled with water. The contents undergo septic decomposition, the solid matter is partially liquefied and the liquid is absorbed into the soil and carried away by the ground water. Because of the depth of the hole, no fly breeding occurs and there is very little odor. The box may be made with a single seat. Bored-hole latrines should be placed several feet apart and so that one hole will not drain into another.

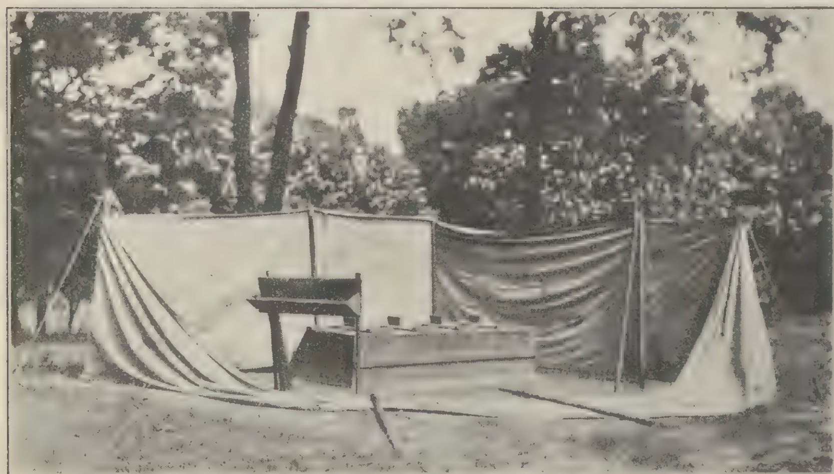


FIG. No. 221. Latrine with screen dropped on one side to show box and urine trough.

The latrine enclosure. Each company, or the equivalent thereof, is usually supplied with standard canvas latrine screens as a part of its organization equipment. The screen is erected as shown in Fig. No. 220. If the standard screen is not obtainable the latrine may be inclosed with a board or brush screen. If the latrine is to be used for a considerable period of time during inclement weather, the inclosure should be roofed to protect the seats and to prevent the earth around the pit from becoming waterlogged.

FIG. No. 222. Pit latrine in a wall tent.

The trough urinal. A trough urinal, as depicted in Fig. No. 217, may be constructed of wood or galvanized iron or tin. If made of wood, it is lined with tar paper to prevent leakage of urine onto the ground under the trough. The trough urinal is usually built to drain into the latrine pit. However, if the latrine pit is in ground having poor absorbing qualities, it may be desirable to prevent liquid from entering the pit and, in such instances, the urinal should drain into a soakage pit.

The soakage pit urinal (Fig. No. 224). The soakage pit urinal consists primarily of a pit in the ground, usually four feet square and four feet deep, which is filled with pieces of broken stone from one to four inches in diameter. If stone is not available, flattened tin cans, broken bottles, broken brick, or pieces of broken concrete may be used as contact material.

The production of odors can be minimized by ventilating the pit. Ventilation is facilitated by placing a layer of stones six to eight inches in diameter on the bottom of the pit, leaving the top of the pit uncovered. Good results can be obtained by installing ventilating shafts on two opposite sides of the pit. Usually, the ventilating shaft is made of four or six inch boards nailed together to form a square shaft, but tiles or stove piping

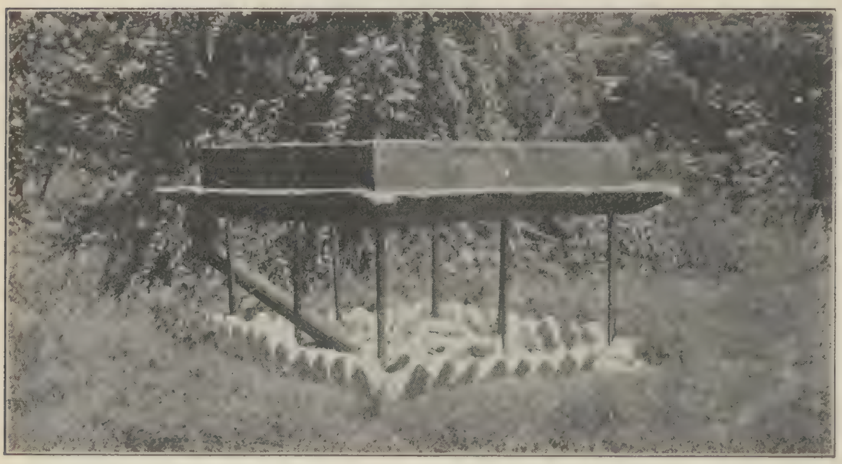


FIG. No. 223. One type of trough urinal and urine soakage pit.

can be used. If the shaft is made of boards, a number of holes should be bored through the side facing the interior of the pit, in order to facilitate air circulation. The shaft should extend from about a foot above the surface to within about six inches of the bottom of the pit. The mouth of the ventilating shaft should be protected by a screen to exclude flies and debris (Fig. No. 224).

Pipe urinals may be made of one and one-half to two inch cast iron or galvanized iron pipes. One such pipe is placed in each corner of the pit at an angle of about 30 degrees from the vertical plane. It extends down for about a foot into the pit and upward for about twenty-four inches above the surface of the pit. A metal or tar paper funnel is placed in each pipe to receive the urine. If necessary, because of lack of space to construct a sufficient number of soakage pits, urine pipes can be placed at each corner and in the center of each side, making a total of eight pipes for each pit. In other instances, a trough urinal may be constructed so that it will drain into a soakage pit (Fig. No. 223).

The principles involved in the operation of a soakage pit are similar to those obtaining in a contact bed (page 686), except that under-drainage from the former is into the soil. While the principal function of a soakage pit is to promote the absorption of the urine by the soil, the organic matter is oxidized

FIG. No. 224. Urine soakage pit. A—Rocks filling pit. B—Ventilator shafts. C—Pipe urinals.

to a greater or less extent during passage over the contact material of the pit.

The efficiency of a soakage pit in the disposal of urine depends on the ability of the soil to absorb fluid. In loose soil, one pit will serve to dispose of the urine of 100 men for an indefinite period.

Location of urinals. A trough urinal draining into a latrine pit is placed within the latrine enclosure. The soakage pit with pipe urinals should, where practicable, be located within the latrine enclosure, but may be outside and provided with a separate screen. Where the soakage pit receives urine from a trough urinal, the trough may be located within the latrine enclosure and the pit outside of the enclosure.

Trench latrines. The trench latrine is utilized only as a means of providing for the disposal of excreta under conditions which render the use of other and safer procedures impracticable. It consists of a trench about one foot wide and not less than eighteen inches, or, preferably, at least twenty-four inches deep. The trench should be long enough to pro-

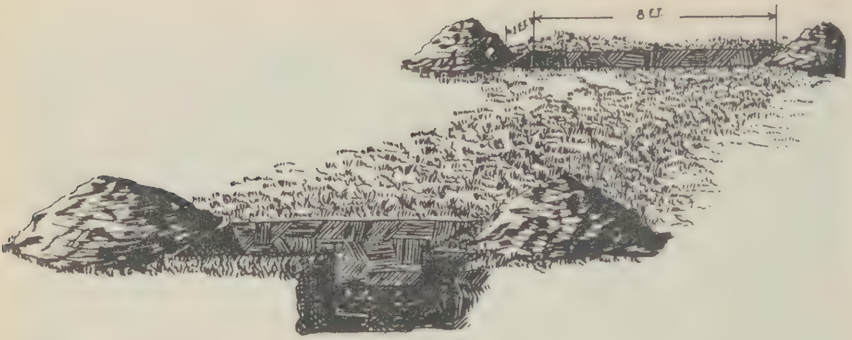


FIG. No. 225. Method of constructing trench latrines. Trench in foreground is cut away to show interior.

vide space for from five to ten per cent of the command, each latrine space being two feet long. The trench latrine may consist of a series of short trenches, two feet long. No seats are provided and the trench is inclosed in a canvas latrine screen or a brush or board inclosure. Urinals are not ordinarily installed in trench latrines. The earth removed in digging the trench should be piled at one or both ends of the trench and used to cover the feces (*infra*).

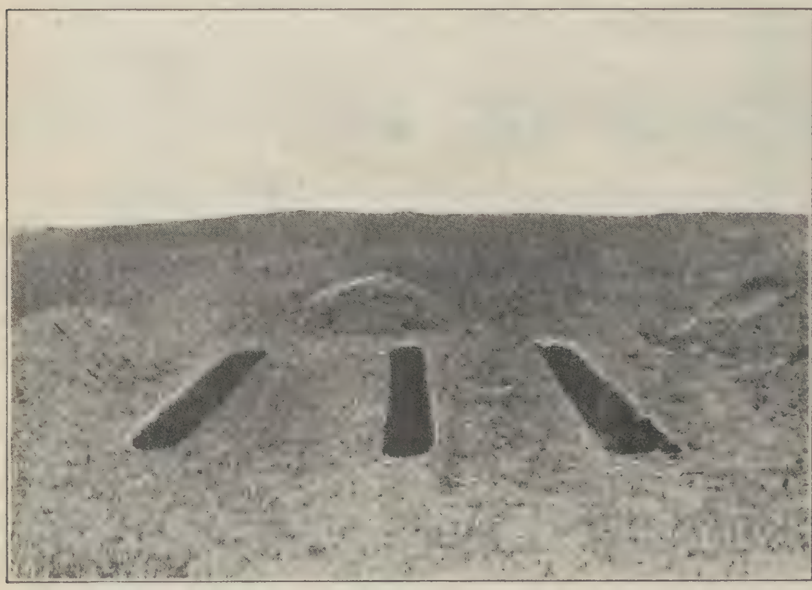


FIG. No. 226. Trench latrine.

Flies have free access to the contents of a trench latrine and may carry pathogenic organisms to the food of the troops. If house flies are prevalent, trench latrines should not be used where it is practicable to install pit latrines.

Location of latrines. In a typical camp, the latrines are located at one end of the company street, or on one flank of the company area at the rear of the tents. The latrines should be, if practicable, at least 100 yards from any company kitchen. A latrine should be at least 100 feet from any well or spring, and areas having an underlying stratum of limestone or tilted rock should be avoided if ground water supplies are obtained in the vicinity.

Care of pit and trench latrines. The latrines should be policed daily by a detail from the organization responsible for their maintenance, or a latrine orderly may be detailed to care for the policing and repair of the latrines. Except in the combat zone, the latrines should be lighted at night. If flies are prevalent, baited fly traps should be placed in or near each latrine.

FIG. No. 227. Latrine inclosure for trench latrine.

Pit latrines. The contents of a pit latrine, the sides of the pit and the interior of the box should be sprayed daily with crude oil. Crude oil will kill the fly larvae with which it comes in contact and also serves to repel the adult insects seeking to enter the pit. It also acts as a deodorant. The exterior of the box and especially the seats should be washed with a two per cent cresol solution at semi-weekly intervals as a cleansing and deodorizing measure. The interior of the trough urinal may be sprayed daily with crude oil to prevent the production of odors.

Chlorinated lime, or some one of the various brands of calcium or sodium hypochlorite, is sometimes placed in latrine pits. These compounds do not prevent fly breeding, and, because of the relatively large amount of organic matter, they have no value as disinfectants. If sufficient quantity is used, they may mask the odor of the feces. In the care of latrines, oil is more satisfactory for all purposes than any chlorine compound, and is usually cheaper.

The latrine pit may be burned out to destroy odors and to prevent fly breeding. Straw, brush, rubbish or oil may be used for this purpose.

When the pit is filled to within two feet of the surface of the ground, the contents should be well sprayed with crude oil and the pit filled with earth. The earth should be domed to a height of twelve to eighteen inches above the surface to prevent the formation of a depression when the contents of the pit settle. If the locality is to be occupied by troops continually, or within the next six months, the site of the closed latrine should be placarded or otherwise indicated to prevent other organizations from attempting to dig a latrine in the same spot.

Trench latrines. If available, crude oil should be sprayed over the contents of the trench each day. Each man should be required to cover his feces with earth, a shovel or board being used for this purpose. When the trench is filled to within one foot of the surface of the ground, the remainder should be filled with earth and domed to one foot above the surface of the ground. The site of the trenches should be marked with a suitable sign, if the area is to be again occupied by troops in the near future.

Care of soakage pit urinals. The surface of the pit and the interior of the funnels, pipes and ventilating shafts should be kept free from debris. If the funnels are made of tar paper they should be removed and destroyed at intervals to

eliminate odors. Crude oil should not be used to deodorize the soakage pit, as the oil will clog the interstices of the soil and interfere with the absorption of the urine.

When a soakage pit is abandoned, either because it is no longer effective or is no longer needed, it is necessary only to remove the pipe and funnels and the ventilating shafts. If it is desired to hide an abandoned soakage pit from view, a few inches of rock may be removed from the surface and replaced with packed earth.

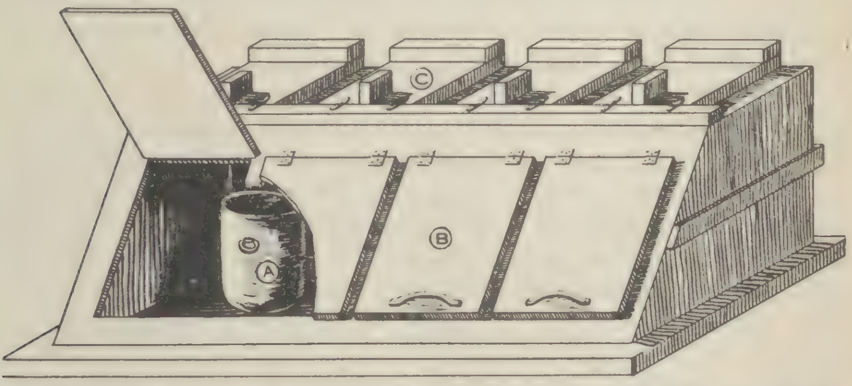


FIG. No. 228. Method of adapting standard latrine box for use as pail latrine. A—Latrine pail. B—Hinged doors. C—Self-closing lids.

The pail latrine. Pail latrines are usually installed for use in buildings, either in latrine rooms in buildings used as barracks or hospital wards where they serve as toilets, or in separate latrine buildings. In tent camps, pail latrines may be housed under canvas but, as a rule, buildings are employed for this purpose.

Where pail latrines are installed, the latrine space provided for a given number of men is the same as when pit latrines are used.

Construction of pail latrines (Fig. No. 228). The latrine box is constructed so that the pail is directly below the seat and can be removed without danger of spilling the contents. When located in a building the latrine should be built in so that the pails can be removed from the rear and from the outside of the building through openings in the wall. These openings should

be provided with hinged doors. The hinges should be exceptionally strong to prevent breakage and can be made of strap iron loops and iron rods or of discarded automobile tire casings. The seats should be equipped with self-closing lids and all crevices or other openings should be made as nearly flyproof as practicable. The quartermaster standard latrine box can be adapted for use with pails by installing hinged doors in the back of the box (Fig. No. 228), or by so modifying the construction that the top can be lifted off to permit the removal of the pails. A trough urinal may be installed within the latrine building with the drain pipe leading into a galvanized iron can placed within or outside of the building. The drain pipe should pass through a hole in a tight fitting lid.

The floor of the latrine should be waterproof and, preferably, should be made of concrete. It should have sufficient slope to promote rapid and thorough drainage of the wash water.

Care of pail latrines. Usually the pails must be removed and emptied once a day. When a pail is removed it should be immediately replaced with a clean pail. The bottom of the clean pail should be covered to a depth of about one inch with a two per cent cresol solution or with crude oil to serve as a deodorant.

The interior of the latrine box and the floor under the box should be scrubbed when the pails are removed. The seats should be scrubbed at least twice a week with a two per cent solution of cresol.

Disposal of the excreta from pail latrines. Ordinarily, the pails containing the excreta are transported in hand carts, animal-drawn wagons, or trucks to some selected point for disposal by burial. If the camp is located near a sewered community, the pails may be emptied through a manhole into a sewer. Under exceptional conditions it may be necessary to dispose of the excreta by incineration. In large camps, a central incinerator, constructed and operated by the Quartermaster Corps, may be employed.

Where practicable, the excreta may be placed in concrete tanks in which it is allowed to undergo decomposition prior to disposal by lagooning or drying, or as fertilizer (page 663).

CHAPTER XVI.

DISPOSAL OF KITCHEN WASTES

GARBAGE DISPOSAL

Garbage is composed of the solid and semi-solid wastes produced in the preparation of food. It includes waste food, the non-edible portions of foodstuffs, and the waste materials incident to the preparation of food, such as tin cans and coffee grounds. It does not include ashes or rubbish, such as street sweepings, rags, wooden or paper boxes, or paper, unless the paper is used to wrap the garbage. The average garbage contains from 65 to 80 per cent of water, and about 85 per cent of the dry matter is combustible. The quantity of garbage produced, exclusive of tin cans, will usually vary from two ounces to one pound per capita per day. Variations in quantity are due to the conditions under which the food is prepared, that is, at permanent messes, in temporary camps or in bivouacs; to the facilities for and the methods of preparing the food, the character and palatability of the food, the training of the personnel, and the measures taken to guard against wastage. In a large camp, the average amount of garbage produced is about 0.8 pounds per man per day. About one-half, by weight, of the garbage is edible and is suitable for food for hogs.

The disposal of garbage at stations and permanent camps involves collection at the point of production, transportation to the place of final disposal and disposal by feeding to hogs, incineration, reduction or composting. The collection of the garbage, including more or less transportation, must of necessity occur within the limits of the military establishment, but the final disposal may or may not take place within the area under the jurisdiction of military authority.

The disposal of garbage in a temporary camp or a bivouac is usually accomplished by burning in company incinerators or by burial. In some instances, disposal may be by regimental or camp incinerator and when this method is used the garbage must be collected and transported to the incinerator.

Sanitary significance. Garbage is of importance as a factor in the transmission of disease, chiefly because it provides food for house flies and serves to attract them in large numbers to the vicinity of kitchens and mess halls where they will have opportunities to infect the food of the troops.

The organic constituents of garbage decompose in a short time and produce odors which create a nuisance if the garbage remains in the vicinity of human habitations.

Disposal by contract. In disposal by contract, the Government enters into a contract with a firm or individual under the terms of which the latter removes the garbage from the military reservation and disposes of it elsewhere. The garbage disposed of by contract may consist of all produced, including both that which is suitable and that which is not suitable for animal food, or it may comprise only that suitable for animal food, or only the grease or bones, leaving the remainder to be disposed of on the military reservation. The contractor may receive the garbage at a central transfer station or he may collect it at the kitchens, mess halls, quarters, or exchanges, where it is produced. The contractor should be bonded to observe the regulations and requirements formulated by military authorities relative to the collection and transportation of the garbage within the limits of the military reservation, as military authority is concerned with the sanitary handling of the garbage until it passes beyond the limits of the military reservation.

The contractor may dispose of the garbage by different methods, but it is usually utilized for hog feed. The methods of disposal employed after the garbage reaches civilian territory are subject to control by state, county or municipal laws and regulations. The Federal Government is not responsible for, and has no legal jurisdiction over, the action of the contractor in disposing of the garbage after it leaves the military reservation, beyond that granted by the terms of the contract. Nevertheless, Medical Department officers who make recommendations relative to the disposal of garbage by contract

should be conversant with and take cognizance of conditions in the civilian community in which it is proposed to dispose of the garbage and the local civilian laws and regulations pertaining to the disposal of the garbage. They should recommend against granting a contract under which the methods used in the disposal of the garbage will violate any of the laws and regulations of local government or infringe upon or endanger the rights or interests of civilian inhabitants from a health or nuisance viewpoint. When garbage is disposed of by contract, the methods by which it is collected and transported, whether this is done by the contractor or by the Quartermaster Corps, are of sanitary significance and should be governed by regulations and orders designed to prevent access to the garbage by house flies and the creation of nuisances.

GARBAGE COLLECTION

The collection of garbage includes its deposition and retention in suitable receptacles and, if required, its classification and separation into different classes at the point of production, and its transportation to the place of final disposal.

Separation. Two general methods of garbage collection are employed in civilian practice—the mixed system and the separate system. When the mixed system is used the garbage is collected in receptacles which contain all other forms of refuse, such as ashes and paper. When the separate system of collection is employed the garbage is separated from other wastes and collected in separate containers. The method adopted depends on the type of disposal procedures employed, but the mixed system is seldom used in the military service.

The separate system of collection, as employed in the military service, usually involves, in addition to the separation of the garbage from the rubbish, the classification of the various constituents of the garbage and the separate collection of the different classes of the garbage.

Classification. Classification and subsequent separation of the garbage into its constituent parts provide a basis for its utilization to the best advantage as animal food or in the recovery of by-products. It also serves as a check on the waste of food, and facilitates disposal by incineration.

Usually, the garbage is classified and separated into that suitable and not suitable for animal food only in posts or permanent camps, as the facilities for the collection of garbage are not ordinarily available in a temporary camp or bivouac.

Classification for animal food. The following articles of garbage are classed as suitable for animal food (edible):

Bread	Scraps of leafy vegetables
Meat and grease	Scraps of prepared food
Bones	Other articles of food
Vegetable peelings	not injurious to hogs.

The following articles of garbage are classed as not suitable for animal food (non-edible):

Coffee grounds	Banana peels and stalks
Tea leaves	Fish heads and fish scales
Egg shells	Citron rinds

Miscellaneous refuse, such as tin cans, paper and other rubbish.

Classification for the recovery of by-products, or as check on the waste of food. Considerable amounts of fats, grease, alcohol, glycerin, nitrogen and potash may be recovered from garbage by suitable reduction processes. However, the treatment of garbage for the recovery of these substances is not ordinarily economically practicable, except in the event of an abnormal shortage, such as might occur during war. Classifications of this nature are based on the kind of material desired, such as for example, grease or bones.

Garbage may be classified and separated into its various components as a means of determining undue wastage of food. Each such component in the garbage is separated and weighed and the classification employed depends on the kind of study being made, that is the total wastage, or the wastage of some particular foodstuff, such as bread or meat.

Classification as combustible and non-combustible. As rubbish is not usually collected with the garbage at a military establishment, the separation of the non-combustible from the combustible portions requires only that such articles as tin cans and bottles be removed from the remainder of the garbage. At times, coffee grounds are also classed as non-combustible.

Collection in garbage cans. The garbage should be collected in standard galvanized iron cans equipped with tight fitting metal lids. These cans are issued by the Quarter-

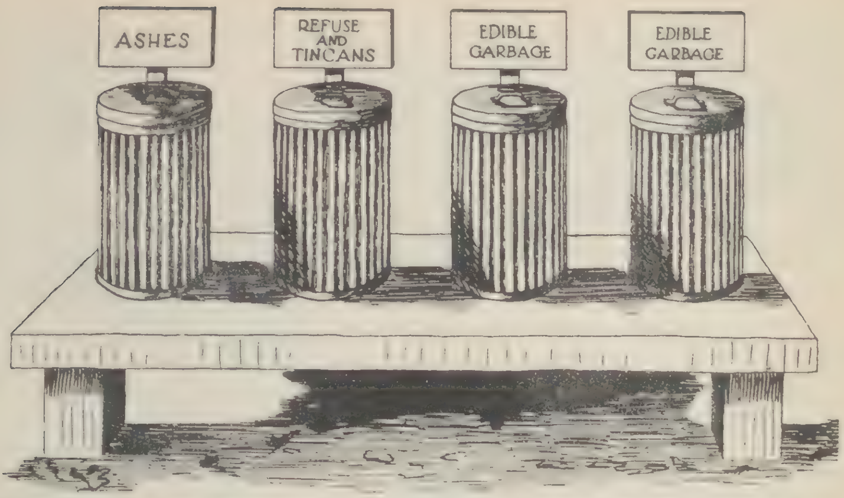


FIG. No. 229. One method of labeling garbage cans for the collection of classified garbage. Concrete garbage stand.

master Corps. The different classes of garbage should be placed in separate cans, over or under each of which there is a sign indicating the class of garbage to be placed in the can (Fig. No. 229).

If the garbage is to be disposed of by feeding to hogs, the edible and non-edible articles are placed in separate cans and the cans so labeled. If the quantity of garbage is sufficient, it may be classified as follows and each of the different components placed in separate cans:

1. Bread.
2. Meats and grease.
3. Bones.
4. Miscellaneous edible garbage.
5. Articles not suitable for animal food (non-edible).

The waste bread may be dried and sacked.

Garbage stands. In posts and permanent camps, stands should be provided upon which to place the cans. These stands should be installed outside of, and adjacent to the kitchens or other buildings in which the garbage is produced. The platforms of the garbage stands are made of wood or concrete and raised at least one foot above the ground on wooden uprights or concrete piers. If the platforms are made of wood, the boards should be laid crosswise and separated by

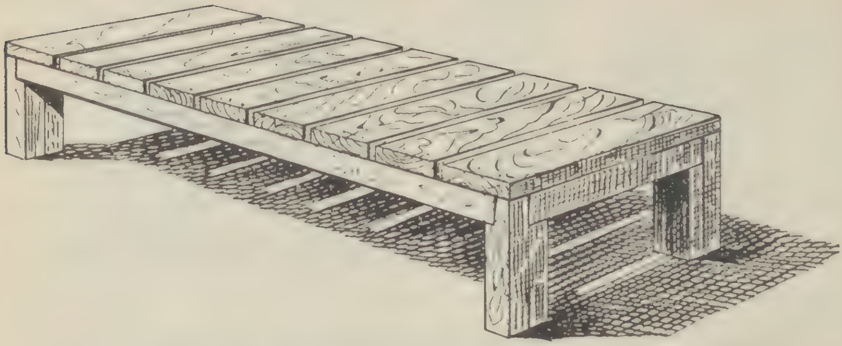


FIG. No. 230. Garbage stand made of planks.

at least one inch to prevent the retention of organic matter between them (Fig. No. 230). Wherever practicable, the platform should be made of concrete to facilitate cleaning and to obviate the creation of a nuisance by the decomposition of organic matter on and in the soil beneath the platform (Fig. No. 229).

Garbage stands should not be screened. Screening does not in any way affect the dissemination of odors and is not therefore a factor in preventing garbage from attracting flies to the vicinity of the kitchens and mess halls. As the screening renders the stand and the area around and under it more difficult to keep clean, a screened garbage stand usually attracts more flies than the one that is unscreened.

Transportation of garbage. The cans containing the garbage should be transported by truck or wagon to the point of ultimate disposal or to a central transfer station. In order to prevent spillage, and the consequent pollution of the soil near the kitchens, garbage wagons or carts should not be used, nor should the garbage be transferred from can to can at kitchens. When a can is removed from the stand the collecting personnel should immediately replace it with a clean can.

After being emptied, the can should be cleansed with hot water and lye, hot soapy water, by steam, and by thorough scrubbing on the inside and outside in order to remove all organic matter that would, if allowed to remain, decompose or attract flies. If hot water is not available, cold water containing lye or other cleansing compound may be used and the cans scrubbed on the inside and the outside with scrubbing

brushes. If the garbage is being fed to hogs, cans which have been cleansed with lye or cleaning compound should be thoroughly rinsed with clear water before being returned to the kitchens. If the garbage is transferred to a contractor's vehicle, the cans should be cleansed at the transfer station or, if there is no transfer station, at the place where the garbage is finally disposed of. Where the garbage is disposed of on the military reservation, the cans should be cleaned at the place of disposal.

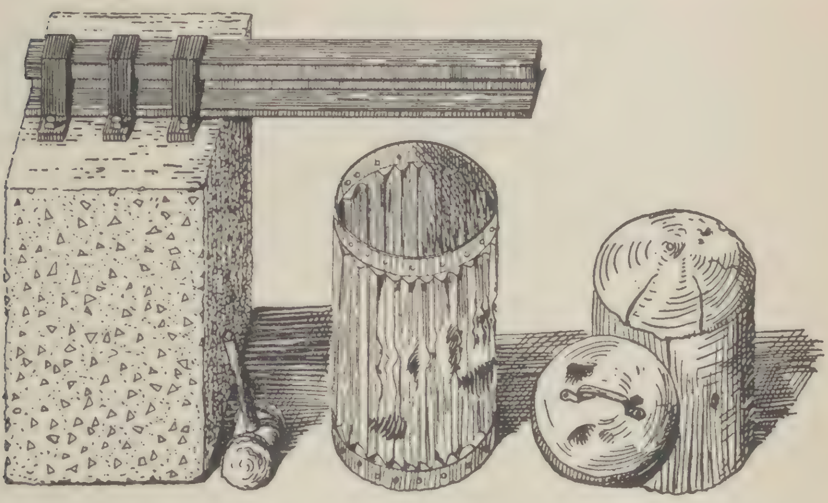


FIG. No. 231. Device used for straightening garbage cans and garbage can lids.

Provision should be made at the place of disposal for straightening dented or battered cans or lids. A suitable anvil for removing dents from cans may be made from a piece of a railway rail as shown in Fig. No. 231. Lids can be straightened over a convex wooden block.

The transfer station. When the garbage is disposed of by contract it is usually necessary, particularly in large camps, to install a central transfer station where the garbage is transferred from the cans in which it was collected at the kitchens to the vehicles of the contractor. The transportation of the garbage in the cans to the place of disposal at some point beyond the limits of the military reservation is not usually a

satisfactory method because of the difficulty encountered in cleaning and returning the cans.

Construction of transfer station. The transfer station for a large station or camp may consist of a platform about 20 feet wide and 100 feet long. At one end of the platform is a store-room for paper and cans, while at the other end is a room or building in which the cans are washed. A rubbish incinerator is usually installed as a part of the station. The platform should be made of concrete and raised above the ground to about the level of the floor of a truck bed.

Can cleaning equipment. The can cleaning equipment consists of long wooden or concrete tanks containing hot water in which a cleansing compound, such as lye, is dissolved. Small compartments may be provided which are equipped with hot water sprays. The dirty cans are soaked in the long vats after which they are scrubbed with stiff brushes or transferred to the small compartments and subjected to strong sprays of hot water.

Operation of transfer station. Trucks deliver the full cans at one side of the platform and obtain clean cans for return to the kitchens from the other side. The full cans containing the edible garbage, or that to be disposed of by contract, are emptied into the trucks of the contractor and the rubbish or useless garbage is sent to the incinerator. The cans are washed in the can cleaning room, repaired if necessary, and replaced on the platform.

The platform and the ground around the station must be kept free from spilled organic matter. The platform should be washed frequently and the waste water drained into a sewer. If necessary, crude oil may be applied to the soil around the platform to prevent fly breeding.

Care of garbage cans and stands. In order to minimize the danger of spilling the garbage during transportation, the cans should not be filled to within more than four inches of the top. The lids should be kept in place at all times while the cans are at the kitchen, except when they are removed for the purpose of depositing garbage in the cans. Care should be exercised that no garbage is spilled on the ground, and if solid garbage is spilled, it should be immediately collected and placed in a can. If the soil becomes soaked with liquid wastes from garbage it will, under suitable climatic conditions, provide a breeding place for house flies.

The platform of the stand should be scrubbed daily with a stiff scrubbing brush and hot soapy water. To prevent fly breeding, the ground around the stand should be sprayed at weekly intervals with crude oil and firmly tamped.

Preferably, the cans should be removed daily and the intervals between collections should not exceed two days in summer or three days in winter.

Garbage cans should not be whitewashed or painted.

METHODS OF GARBAGE DISPOSAL

The primary and principal purpose of any method of garbage disposal is to obviate the creation of nuisances and to prevent house flies from being attracted by accumulations of garbage to the vicinity of kitchens and messes. The general methods employed for the disposal of garbage are reduction, feeding to hogs, incineration, burial and composting.

Disposal by reduction. In disposal by reduction, the garbage is cooked and so treated that the liquid and solid portions are separated and the grease recovered. While both the grease and the residue, or tankage, have a certain value, the high cost of constructing, maintaining and operating a reduction plant renders it impracticable, from a financial viewpoint, for use by a community of less than 50,000 population. Consequently, the disposal of garbage by reduction is not feasible for military establishments.

Disposal by feeding to hogs. Disposal of garbage by feeding it to hogs is an economical method where sufficient garbage is produced. The creation of a nuisance can be avoided by keeping the hogs a suitable distance from inhabited buildings and by the proper operation of the feeding lot.

The disposal of garbage by feeding to hogs is not usually a feasible method for a station or camp having a strength of less than 500 troops. Hogs ranging in size from small pigs to large sows will consume an average of 15 to 20 pounds of garbage per animal per day. Five hundred troops will produce about 200 pounds of edible garbage per day, or sufficient to feed from 10 to 15 animals.

The garbage intended for hog feed should be carefully separated at the kitchens from all articles not suitable for animal food, and it should be drained to eliminate soap, lye,

and sink liquids. As the garbage has a higher food value when fresh, it should be collected at daily intervals.

Garbage-fed hogs are constantly subjected to exposure to disease, particularly hog cholera and tuberculosis, and losses from disease should be anticipated when this method of garbage disposal is being considered. Garbage-fed hogs should always be immunized against hog cholera.

Meat, or meat products, produced from garbage-fed hogs may serve to transmit trichinosis to the consumer. If such meat is issued to troops, care must be taken that it is well cooked before being served (page 197).

Incineration. Garbage incineration consists of burning the garbage in some kind of furnace until the combustible portions are completely consumed. Burning garbage produces malodorous gases which, unless they are decomposed by heat during the process of incineration, may create a nuisance. Incineration is the ideal method of garbage disposal in so far as control of house flies is concerned, and if the gases are consumed, also as a means of preventing the production of a nuisance.

Essential features of garbage incineration. The economical and effective disposal of garbage by incineration requires that the incinerator be so constructed that the garbage is preheated and partially dried so that it will burn freely, and that the gases released by drying and burning garbage are decomposed before escaping from the incinerator.

In general, in the incinerators that meet these two requirements, the garbage is dried on a drying grate, rack, or hearth on which the wet garbage is placed or dumped. Below or adjacent to the drying grate is a fuel grate on which the dried garbage from the drying grate is burned and from which heat is obtained to dry a fresh charge of garbage on the drying grate. In other and less efficient types, the garbage is placed directly on the fire, the same area or grate serving to dry and burn the garbage.

A minimum temperature of 1250°F., with an average temperature of at least 1400°F., is required to decompose the obnoxious gases produced by drying and burning garbage. The incinerator must have a combustion chamber in which the decomposition of the gases can be effected. In order to dry and burn wet and sometimes frozen garbage and produce an average tem-

perature of 1400°F., a draft must be provided. Consequently, the gases can be consumed only in a closed incinerator equipped with a suitable stack.

Closed incinerators. The closed incinerator is essentially a furnace equipped with fuel and drying grates and having a combustion chamber and a relatively high stack. The low temperature, closed incinerator operates at an average temperature of about 1400°F. The high temperature type develops a minimum temperature of 1800°F. The cost of constructing a low temperature closed incinerator is less than for a high temperature plant, but it is difficult to operate a low temperature plant so that a charge of fresh garbage will not reduce the temperature below 1200°F., and thus permit malodorous gases to escape. On the other hand, the high temperature which is maintained at all times in a high temperature incinerator will effectively decompose all malodorous gases. As one of the primary objectives sought when a closed incinerator is installed is the elimination of nuisances due to odors, the high temperature types are generally more satisfactory at a military station or camp.

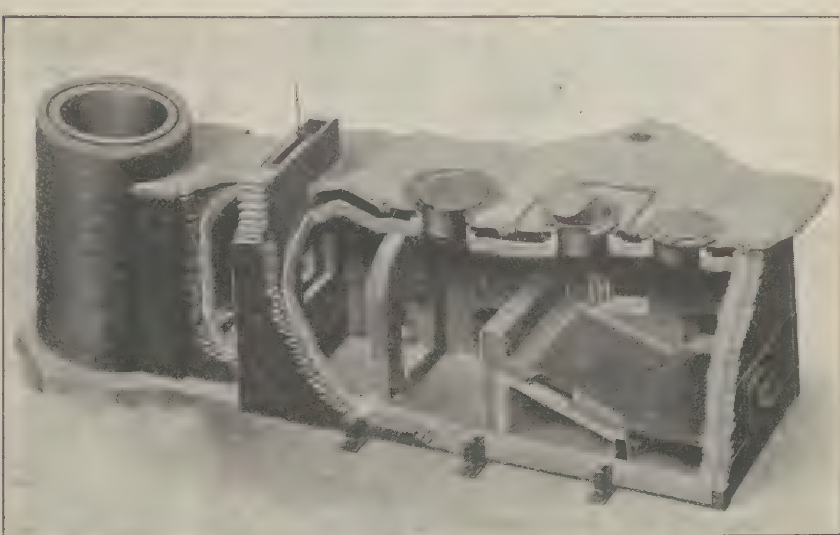


FIG. No. 232. U. S. Standard incinerator. This incinerator has a stack about 50 feet in height. (Courtesy of the Pittsburgh—Des Moines Steel Co.).

The United States Standard Incinerator (Pittsburgh - Des Moines Incinerator) is a typical high temperature, closed incinerator (Fig. No. 232). The garbage is dumped onto an inclined drying grate through a charging opening in the top of the incinerator, and the dried garbage slides down onto the fuel grate to be consumed. The superheated gases pass backward through a throat into a combustion chamber where they are decomposed by heat. The arched roof of the furnace and a heavy wall of fire proof material prevent lateral expansion and distortion due to the high temperatures. A stack is provided which, for a five ton installation, is about 50 feet in height.

The closed incinerator is usually provided with a platform onto which the full cans are unloaded and from which the empty cans are removed by the garbage trucks or wagons. Usually, can washing equipment, consisting of a concrete soaking tank and spraying compartment, is provided as a part of the installation.

Other types of closed incinerators differ from the United States Standard Incinerator only in details of construction, the same basic principles being involved. Closed incinerators may be employed to dispose of a minimum of from one to twenty tons of garbage daily.

The closed incinerator is a Quartermaster Corps installation and is constructed and operated by that branch, as its minimum capacity precludes its use by companies or equivalent organizations.

Advantages and disadvantages of the closed incinerator. A properly constructed and operated closed incinerator will completely destroy all the garbage without producing odors or obnoxious smoke. It requires less fuel under average conditions than the open type incinerator. The absence of nuisance production renders it practicable to operate the closed incinerator near inhabited buildings. The heat produced can be utilized to provide hot water or steam for washing the cans.

The closed incinerator has the disadvantages that it can not be operated economically for the disposal of small amounts of garbage, that is, less than about one ton daily, and that the cost of construction is comparatively high. The high temperatures, which are essential for the efficient operation of the plant,

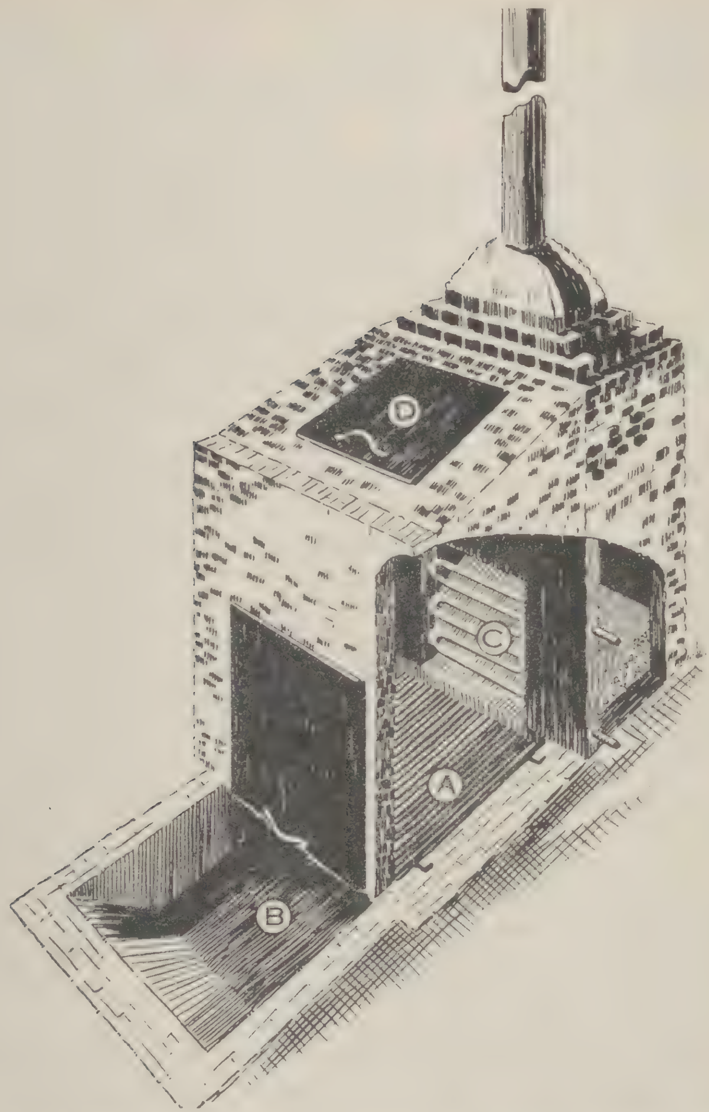


FIG. No. 233. Semi-closed garbage incinerator (Schematic). A—Grate bars on which the garbage is burned. B—Fire box. C—Hot water coils. D—Charging door through which the garbage is passed into the incinerator.

render frequent repairs necessary and increase the maintenance, depreciation and operating costs.

The operation of a closed incinerator requires constant, skilful supervision to prevent damage to the incinerator or the creation of a nuisance due to the escape of gases.

Semi-closed incinerators. The semi-closed incinerator embodies certain of the features of the closed type. It has a relatively low stack which assists in creating a draft, and is protected from rain, wind, or flooding with ground or surface water. The most important difference between the closed and the semi-closed types is that in the latter the heat generated is not sufficient to burn the gases and there is no combustion chamber in which the gases can be decomposed.

The details of construction of one type of semi-closed incinerator are shown in Fig. No. 233.

The semi-closed incinerators can be effectively employed for small permanent installations, such as hospitals, supply depots, or small camps, where the amount of garbage to be disposed of does not justify the construction of a closed incinerator. They are superior to the open type of incinerator in that they have a better draft and can be more efficiently operated in inclement weather. Also, the nature of the construction permits the use of coils for heating water for can-washing or other purposes.

The semi-closed types are easier to build with unskilled labor than are the closed types and the materials required for their construction are frequently more readily available.

The semi-closed incinerators are less efficient than the closed types in that they produce obnoxious odors due to the undecomposed gases, and have considerably less capacity per unit of grate area. Furthermore, they frequently must be constructed of ordinary brick instead of fire brick, with the result that they deteriorate more rapidly.

Open incinerators. Generally, the garbage produced in a temporary camp must be disposed of within the area occupied by the troops and without the aid of permanent installations, such as the closed incinerator. As a rule, the garbage must be disposed of in open incinerators or by burial.

Open incinerators have no stack and therefore no draft, other than that produced by the wind and heat. The gases are not decomposed and there is inadequate or no preheating

and drying of the garbage. Consequently, they create nuisances due to obnoxious odors. Open incinerators are emergency installations and are used only when the garbage can not be disposed of by contract, feeding to hogs, or by incineration in closed or semi-closed incinerators.

Basically, the open incinerator is a pit in which the garbage is burned by being placed directly on a fire or on a grate immediately above the fire. Variations in the construction of the different types are made with a view to improving the draft or providing facilities for drying the garbage.

Owing to the great loss of heat in open incinerators and the low fuel value of the garbage, fuel must be used to dry and burn the garbage. Usually, wood is used as fuel and the garbage must be incinerated in small amounts, as the fire is easily smothered by fresh or wet garbage.

All combustible rubbish should be burned as fuel in the incinerators. Measures should be taken to prevent paper, excelsior or other light rubbish from being blown about the camp from the vicinity of the incinerators. The tin cans should be burned to destroy any remaining organic matter. After burning, the tin cans, fragments of bones, and other noncombustible material are removed from the incinerator and disposed of by dumping or burial. If mosquitoes are present in the vicinity, the tin cans should be flattened with a sledge or the back of an ax helve prior to final disposal in order to prevent the collection and retention of water in which mosquitoes might breed.

The principal types of open incinerators are the rock pile incinerator, the multiple shelf incinerator, the drying pan incinerator, the barrel and trench incinerator and the rock pit incinerator. Each type is susceptible of many modifications and the descriptions given below present only the basic principles involved in the construction and operation of the type of incinerator concerned. In each instance, the actual details of construction and method of operation would be governed by local requirements and conditions.

Open camp incinerators. An open camp incinerator is employed where it is desired to burn in one incinerator the garbage produced by two or more units. Open camp incinerators are necessarily larger than company incinerators (*infra*). They are, as a rule, operated by Quartermaster Corps

personnel or by police details under the supervision of camp, regimental or battalion headquarters.

There are two general types of open camp incinerators—the rock pile incinerator and the multiple shelf incinerator. Either of these types can be designed to burn the garbage produced by a regiment, or by a body of troops corresponding to a regiment in strength.

A rock pile or a multiple plate incinerator should be located as far as practicable from the barracks or tents of the troops, preferably at least 500 yards. Garbage must be collected at the company kitchens and transported to the incinerator. The methods of collection are the same as when closed or semi-closed incinerators are used.

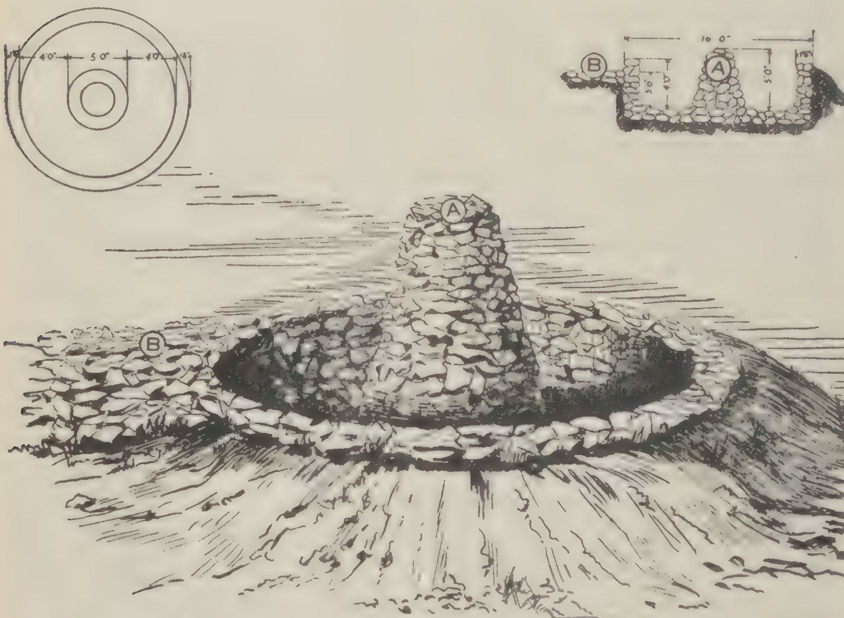


FIG. No. 234. Rock pile regimental garbage incinerator. A—Center cone. B—Rock platform on which garbage cans may be unloaded from wagons or trucks.

The rock pile incinerator (Fig. No. 234). The rock pile incinerator is usually employed for the disposal of the garbage for more than one company. It consists of a circular pit in the center of which is a cone to divert the air currents upwards and thus create a draft. The walls, bottom and cone are made of

loose rock (rubble). The pit is about 16 feet in diameter and from 24 to 30 inches in depth (inside measurement). The floor should be from 12 to 18 inches thick and the walls from 8 to 18 inches thick. The portion of the wall above the surface of the ground should be supported on the outside by an earthen or rock embankment. The central cone extends five feet above the bottom of the pit and is three to four feet in diameter at the base and six to twelve inches at the apex. An apron of rock from six to twelve feet square should be constructed at one side of the pit on which the full cans of garbage may be placed when removed from the garbage trucks or wagons.

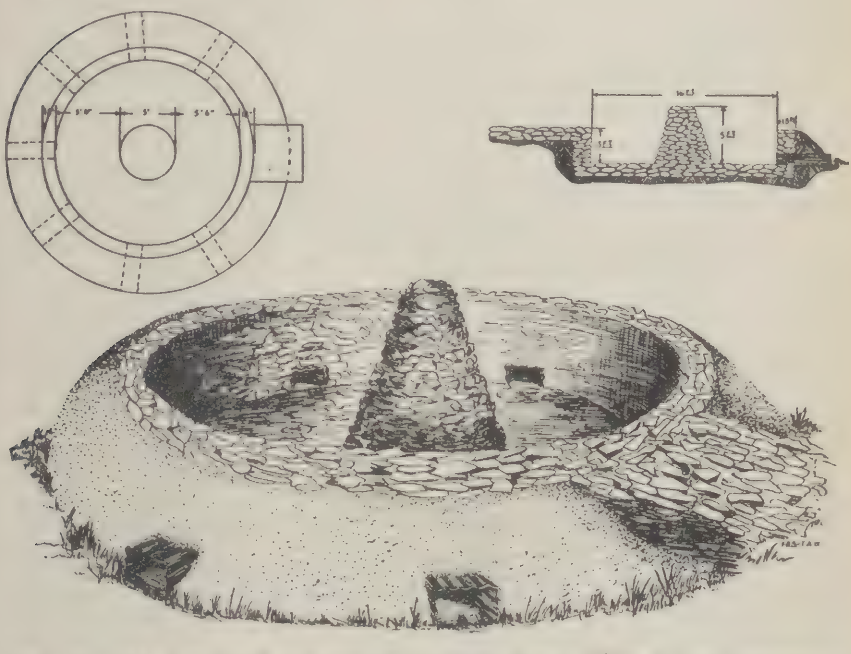


FIG. No. 235. Rock pile incinerator showing draft holes at the junction of the wall and bottom of the pit.

One variation in the construction of a rock pile incinerator is effected by the installation of from four to eight draft holes at the junction of the wall and the bottom of the pit (Fig. No. 235). These holes are from six to twelve inches in diameter and are spaced at equal distances around the circumference of the pit. They open outward into tunnels or trenches which lead to the surface of the ground outside the wall of the pit. The upward

movement of the heated air from the pit creates a draft which draws fresh air through the draft holes into the fire in the incinerator.

In the operation of a rock pile incinerator, a fire is built between the cone and the side wall on the windward side of the cone. The garbage should be transferred directly from the cans to the fire to avoid soiling the ground. It may be partially dried prior to burning by being placed between the fire and the side wall. The cans should be cleaned before being returned to the kitchens.

The rock pile incinerator possesses certain major disadvantages. A large amount of dry fuel is required to maintain a fire that is hot enough actually to burn the garbage. Where an ample quantity of dry fuel is not used, or during rainy weather, the garbage becomes a smoldering mass requiring a long time to burn and giving off large quantities of smoke and malodorous gases.

The multiple shelf incinerator. The multiple shelf incinerator is a rectangular brick stack containing a fire grate, above which there are from four to six shelves which serve as drying grates (Fig. No. 236). It varies in size depending on the design capacity, but is usually three to five feet wide, four to six feet long, and eight to twelve feet high. The bottom of the stack forms an ash pit, immediately above which are grate bars of two inch iron pipes. The ends of the grate bars are so placed that they can be readily removed when warped by heat.

The shelves are placed from eighteen to twenty-four inches apart from the fire grate to the top of the stack. They are installed so that a slot from ten to fifteen inches wide is left between each shelf and the wall on one of the long sides of the stack. These slots are on alternate sides of the stack so as to form a zigzag air channel from the fire grate to the top of the stack. The upper shelf is placed about six inches below the top of the stack. The shelves should be made of one-fourth inch boiler plate. In cutting the shelves, at least one inch tolerance should be allowed for expansion on each of the three sides next to the walls.

Each shelf rests on supports consisting of fire brick embedded in the walls on three sides of the stack and two iron or steel bars extending across the stack under the shelf. The iron bars should be wrought iron, but pieces of railroad rails may be used.

The ends of the bar supports are inserted into openings in the stack walls and supported by metal plates to prevent the weight from breaking the brick. The outer ends of these openings are closed by loosely placed brick or concrete blocks in order that the

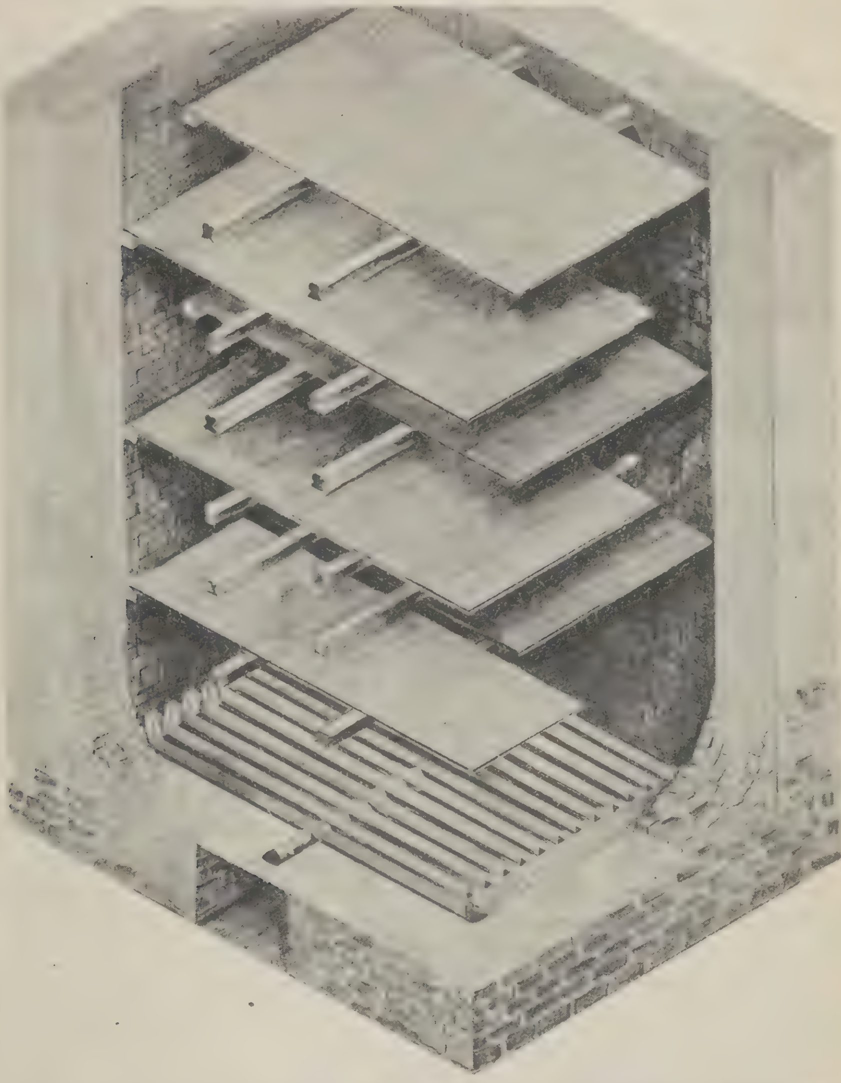


FIG. No. 236. Multiple shelf incinerator with side cut away to show interior construction.

bars can be readily removed for straightening when warped by heat.

Two stoke holes are placed in the wall immediately above the closed side of each shelf through which, by means of a hoe or rake, the garbage is distributed on the shelf, or pushed through the slot onto the shelf or fire grate below. Each stoke hole is equipped with an iron door.

The space between the grate and the lowest shelf constitutes the fire box. The fire box is equipped with a substantial iron door.

The multiple shelf incinerator is placed in operation by first loading each of the shelves with about four inches of garbage. A brisk fire is then started on the grate in the fire box. When the garbage on the lower shelf is dried and begins to burn it is pushed off onto the fire below and the garbage on each of the shelves above is moved down one shelf. A fresh charge is then placed on the uppermost shelf. This operation is repeated whenever the garbage on the lower shelf begins to burn. Hoes or rakes passed through the stoke holes are used to move the garbage.

In the multiple shelf incinerator, the metal plates and supports are exposed directly to the heat and if too much heat is produced, they will warp in a short time and render the incinerator useless. In order to prevent warping, the lower shelf should be heated only until the metal shows a faint tinge of red, when the draft should be checked by opening the stoke hole doors or the fire box door. The men in charge of the apparatus should be trained to watch the lower shelf through the stoke hole doors and to check the draft or reduce the fire whenever the metal shows a red color.

The low temperature required to prevent warping of the shelves and shelf supports is frequently difficult to maintain. The shape of the incinerator is such that a good draft is produced and consequently an excessively high temperature is easily reached. The operating personnel must be well trained and carefully supervised to prevent the apparatus from being ruined by high temperatures.

A platform should be built to receive the full cans of garbage. Hot water for washing the cans may be obtained by means of hot water coils in the incinerator.

Multiple shelf incinerators are usually installed only at permanent stations or camps. In the multiple shelf incinerator, the

garbage is slowly dried and partially cooked with the result that malodorous gases are produced while the low temperature which must be maintained permits smoke to form and escape. As it has no stack, the gas and smoke produced by the cooking and drying garbage are released into the atmosphere at practically ground level and frequently produce a serious nuisance.

The multiple shelf incinerator when properly operated requires much less fuel, in addition to the garbage, than any other type of open incinerator. Further, if it is properly constructed, wind and rain interfere but little with its operation.

Company incinerators. Company incinerators are improvised open incinerators designed to burn the garbage produced by one company or an equivalent body of troops. The principal types are the drying pan incinerator, the barrel and trench incinerator and the rock pit incinerator.

FIG. No. 237. Drying pan incinerator with Sibley stove used as stack.

The drying pan incinerator (Fig. No. 237). The drying pan incinerator consists of a pit, the walls of which support two sheet iron pans for evaporating liquids. The pit is six feet long, eighteen inches wide, and eighteen inches deep, inside measurements. The walls are made of brick or concrete and are ten to twelve inches thick. The stack consists of a

Sibley stove or may be made of sheet iron with a flaring base. The pans are twenty-two inches square and six to eight inches in depth.

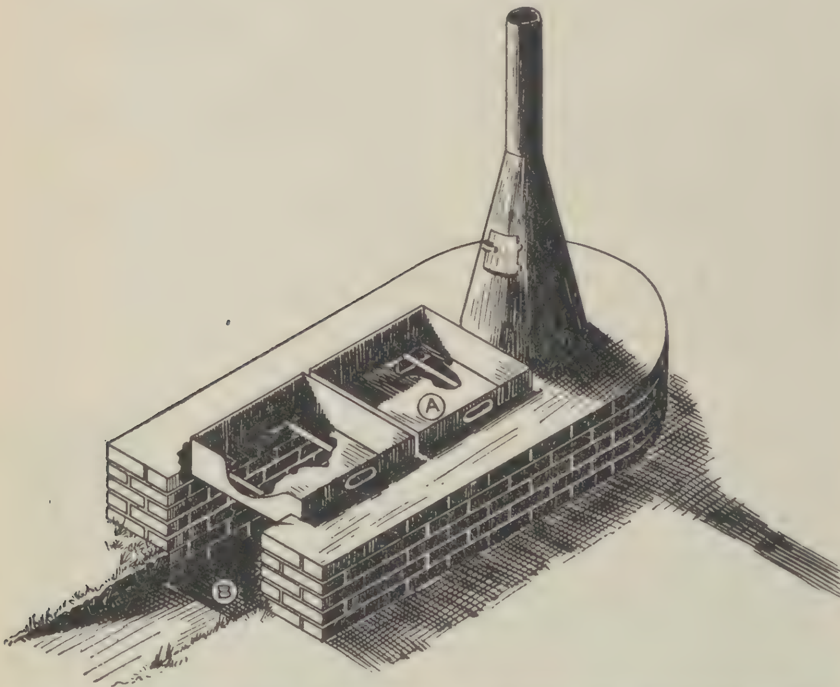


FIG. No. 238. Drying pan incinerator. A—Drying, or evaporating pans. B—Fire box.

The barrel and trench incinerator (Fig. No. 239). The barrel and trench incinerator consists of a barrel-like stack which is placed over the intersection of crossed trenches. Two trenches one foot wide and ten feet long are so constructed that they cross at right angles at the center of each trench. Each trench slopes from the surface of the ground at each end to a depth of eighteen inches in the center at the intersection.

The stack provides means for pre-heating and partially drying the garbage prior to burning. It may be made of brick laid without mortar and is about 4.5 feet in diameter at the bottom and three feet at the top (outside measurements), and about 2.5 feet high. The garbage grate is made preferably of strap iron, but small iron pipe or bars may be used. The

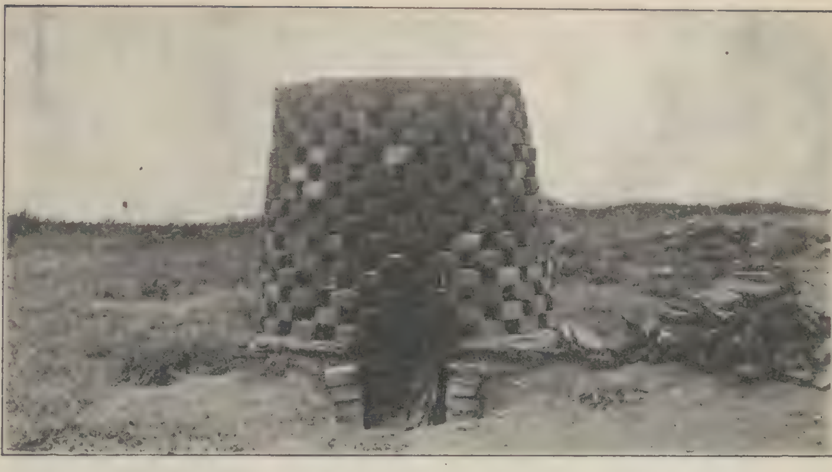


FIG. No. 239. Barrel and trench incinerator with the barrel made of brick.

ends of the grate material are anchored in the walls of the brick stack about six inches above the ground and about three or four inches apart.

If bricks are not available, pieces of stone may be used in lieu thereof, or the stack may be made of clay. If made of clay, a wooden barrel with both ends removed is placed over the inter-

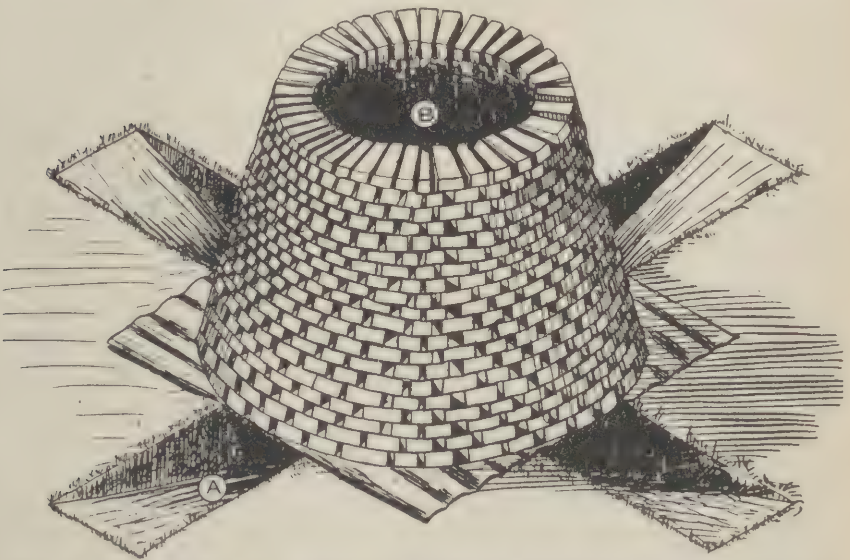


FIG. No. 240. Barrel and trench incinerator. A—Trenches which serve as fire boxes. B—Barrel to receive garbage.

section of the trenches and utilized as a mould. Puddled clay is molded around the barrel to a thickness of from six to twelve inches (Fig. No. 241). The grate irons are inserted into the clay through holes in the barrel about six inches above the surface of the ground and about three or four inches apart. A small fire is then made in one of the trenches so that the clay is slowly dried over a period of several hours without burning

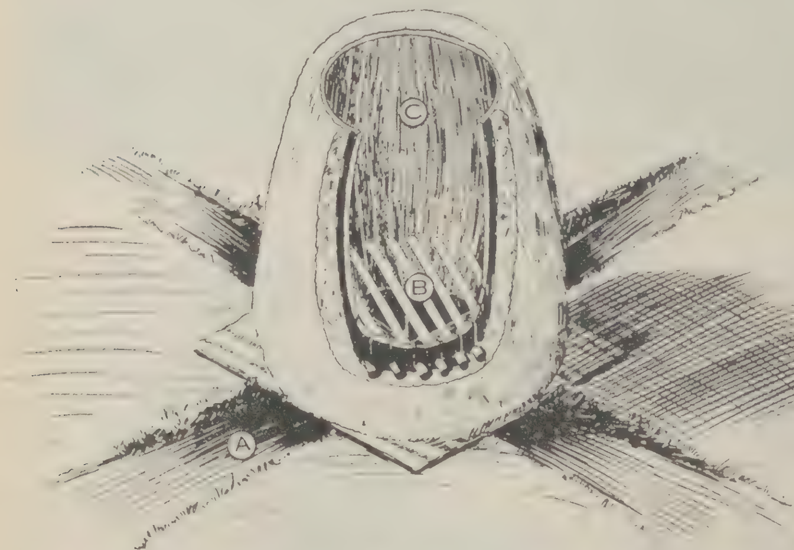


FIG. No. 241. Barrel and trench garbage incinerator. A—Fire trenches. B—Grate bars. C—Wooden barrel, with surrounding clay, which is burned out leaving the clay mold intact.

the wooden barrel. After the clay is well baked a brisk fire is built under the barrel and the wooden mold is burned out. Rapid drying may cause the clay to crack and disintegrate. A clay incinerator will remain serviceable under ordinary conditions for about two weeks. The addition to the clay of from ten to twenty per cent of lime, by volume, will render the finished product more solid. If the barrel used as a mold has iron hoops, the hoops will remain embedded in and help to support the clay after the barrel has been burned out. The barrel may be wrapped with wire which will serve the same purpose as iron hoops.

A brick, stone, or clay stack is supported over the trenches by wide pieces of corrugated iron, or sheet iron, or by strips of strap iron, iron bars, or iron rails.

FIG. No. 242. Barrel and trench incinerator with the barrel made of packed clay molded over a wooden barrel.

A galvanized iron garbage can with the bottom removed may be used as a stack where materials are not available for the construction of other types. The can is placed on the grate bars which are laid on the ground so as to pass over the trench intersection (Fig. No. 243).

The rock pit incinerator (Fig. No. 244). The rock pit incinerator is a U-shaped pit made of rock or clay. It is about 4.5 feet long, 2 feet wide and 18 inches deep. The walls are usually made of stones or rubble and are from six to twelve inches thick. If stone is not available for this purpose, puddled clay or soil may be used. The floor of the pit consists of a layer of stone or tamped earth. In order that a suitable draft may be obtained, the floor should be flush with, or but slightly below the surface of the ground.

Operation of company incinerators. Usually, the greater proportion of the garbage is incinerated as it is produced so that collection in cans is not necessary. In the operation of the rock pit and drying pan incinerators, the garbage to be burned is placed directly on the fire. In the case of the barrel and trench incinerator, the garbage is thrown on the garbage grate through the top of the stack where it dries and drops or is pushed down onto the fire below.

The drying pan, the barrel and trench, and the rock pit incinerators are company installations, and are, therefore, nor-

FIG. No. 243. Barrel and trench incinerator with barrel made from galvanized iron garbage can from which the bottom has been removed.

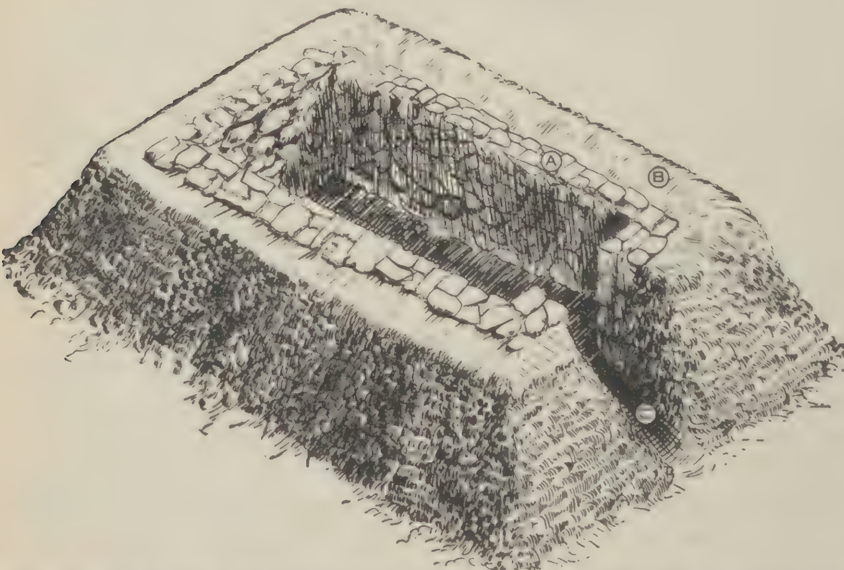


FIG. No. 244. Rock pit incinerator (Schematic). A—Rock wall. B—Earthen embankment to support rock walls. C—Open end to permit draft.

mally located adjacent to the company kitchens so that the garbage can be burned as produced.

The barrel and trench incinerator is the most efficient of the company incinerators. It has a better draft than either the drying pan or the rock pit incinerator and, as the garbage grate in the barrel provides a means for partially drying the garbage prior to incineration, the fire can be more easily maintained. Wind and rain storms interfere less with the operation of the barrel and trench incinerator than with either of the other company incinerators.

The drying pan incinerator may be used where the liquid wastes cannot be disposed of except by evaporation. Otherwise, it is not as efficient as either the barrel and trench or rock pit incinerator.

The rock pit incinerator may be installed where the kitchen will be in operation for only a few days, or where materials for the construction of a barrel and trench incinerator can not be obtained.

When properly operated any of the company incinerators will suffice for the disposal of the garbage produced by an infantry company at war strength.

Burial. Where space is available, burial is an effective method of disposing of garbage. Ordinarily, trenches from two to three feet in depth are utilized for the burial of large quantities of garbage. A trench is filled with garbage to within about one foot of the top and then back filled and domed with earth. A shallow trench about ten to twelve inches deep may be used. Garbage is placed in the trench to a depth of about six to eight inches and the trench is back filled and domed with firmly packed earth. In the tropics, or during summer elsewhere, it may be advisable to spray the garbage in shallow trenches with crude oil to prevent fly breeding. Garbage buried in shallow trenches will decompose more rapidly than that buried in deep trenches or pits, but shallow burial has the disadvantage that the garbage may be uncovered by storm water or by animals. Garbage may be buried in deep pits, but usually this is not a practicable procedure because of the labor required.

The area required for the burial of garbage depends on the method used and on the character of the soil. The soil should be well drained and consist of loam or loam and sand. Soil containing any considerable proportion of clay is not usually satis-

factory. Given suitable soil, about 2500 square feet of ground will be required for the burial of the garbage produced by 100 troops in one month, where the garbage is buried in deep trenches (*supra*). The land may be used again for the burial of garbage after about three years.

The large area of land required, the amount of labor involved and the difficulties encountered in burying garbage in frozen ground usually render this method of disposal impracticable for stations or permanent camps.

In bivouacs or temporary camps. In bivouacs, or in temporary camps of from one to three days duration, garbage is, as a rule, disposed of by burial. Usually, a pit of suitable size is dug near the company kitchen. When filled with garbage to within about one foot of the surface, the pit is back-filled with earth which is firmly tamped down. At times it may be practicable and desirable to install one pit for the disposal of garbage from two or more company kitchens.

A garbage pit should not be within 100 feet of any source of water used for drinking or cooking.

Composting. Garbage may be placed in compost bins (page 782) where it will undergo decomposition and eventually be reduced to a mass of stable material. In the Becarri method the garbage is placed in a concrete or brick cell or bin which is about ten feet square and ten feet deep. The filled cell is tightly closed and allowed to remain closed for from 35 to 45 days or longer. It is claimed that by this method the garbage is reduced to a humus-like material which has no offensive odor and which can be dried and used as fertilizer without creating nuisances. The Becarri system is patented.

Disposal with sewage. Where a sewerage system is available, the soft garbage can be disposed of with the sewage. The garbage, except bones and other hard substances, is reduced to a finely divided state by means of special apparatus, such as a comminutor or shredder, and disposed of with the liquid wastes from the kitchen. This method would be seldom practicable at a military station or camp.

DUMPS

Certain kinds of garbage, particularly tin cans and burned bones, may be disposed of on dumps. From a sanitary point of view dumps are of importance only in so far as they afford harboring places for rats or contain organic matter which may serve as breeding material or food for flies.

At military posts and camps, all kinds of non-combustible wastes and refuse are disposed of by dumping. As it is difficult to prevent small amounts of putrescible organic matter and combustible materials from reaching the dump, an incinerator in which such material can be burned should be installed at the dump.

The dump should be located where it will produce the least nuisance due to appearance and odors. If practicable, a dump site should be selected where the dumped material will serve to fill a low area, which will be improved if the grade is raised.

Construction. A bank fill dump should always be made with a face not less than eight feet nor more than twelve feet in height. Where practicable, the dump should be built on a hill side so that the surface may be made approximately level. If the dump is built on level ground, the surface should slope gradually upward until the face has a depth of between eight and twelve feet. A depth of less than eight feet will not permit the larger articles to be properly covered and removed from view, while a depth of more than twelve feet will frequently result in bulging, sliding, or caving out of the face of the dump.

The face of the dump should be kept vertical, or as nearly so as practicable. Backing logs of heavy timbers should be placed along the upper edge of the face against which the loaded vehicles may back and dump their loads down the face of the dump. When vehicles are used which are not equipped for dumping, they are driven along side of the backing logs and unloaded by throwing the material over onto the face of the dump.

Maintenance. As each load is dumped, the face of the dump should be trimmed and all combustible material removed and burned in the incinerator. Any article having market value, or which can be used for any purpose, should be

salvaged and removed from the dump. All large or unsightly articles, or materials which will interfere with plowing or ditching the surface of the finished dump, should be placed on the bottom of the dump or, if necessary, broken up.

As the dump is completed, the top and sides should be covered with material which will support vegetation. Earth, or earth mixed with ashes or manure, should be used for this purpose.

DISPOSAL OF LIQUID KITCHEN WASTES

In a station or camp which is provided with sewerage, the liquid kitchen wastes are disposed of as sewage, but in camps where no sewers are available, other methods must be adopted to dispose of these wastes. In some situations it may be practicable to collect the liquids in galvanized iron cans which are then hauled away in a truck or wagon to be emptied into a sewer manhole or on the surface of the ground at some isolated spot. Usually, however, liquid kitchen wastes are disposed of in the soil by means of soakage pits or trenches at or near the place where they are produced.

Soakage pits. The soakage pit for the disposal of kitchen wastes is constructed in the same manner as the soakage pit for the disposal of urine (page 729), except that pits for the disposal of kitchen wastes should be equipped with a grease trap.

The filter grease trap. The filter grease trap may consist of a galvanized iron pail or large can in the bottom of which a number of small holes are punched. The pail is placed in the center of the top of the pit with the bottom about two inches below the surface. It is filled two-thirds full with a filtering material consisting of hay, grass, straw, or cloth, which catches and retains a part of the grease and the debris, such as bread crumbs, or vegetable fragments. The filtering material may consist of a layer of gravel or broken stone or brick on the bottom of the container above which is a layer of ashes, charcoal or fine çoal.

Where a larger quantity of liquid is to be disposed of, a wooden barrel, or a metal or wooden tub, may be used instead of a pail or can. A barrel or tub has the advantage that, having a greater diameter, it will produce a wider initial disper-

FIG. No. 245. Grease trap made of pail. A—Filtering material consisting of straw, grass, excelsior or cloth. B—Bottom of pail in which numerous small holes are punched.

sion of the liquid as it enters the pit. Also, larger quantities of liquid can be poured into the trap without spilling, and the filtering material can be more easily removed with a shovel.

The top of the trap may be covered with burlap to strain out the larger pieces of debris. The burlap should be removed daily and thoroughly cleaned, or burned or buried, and replaced with a clean piece.

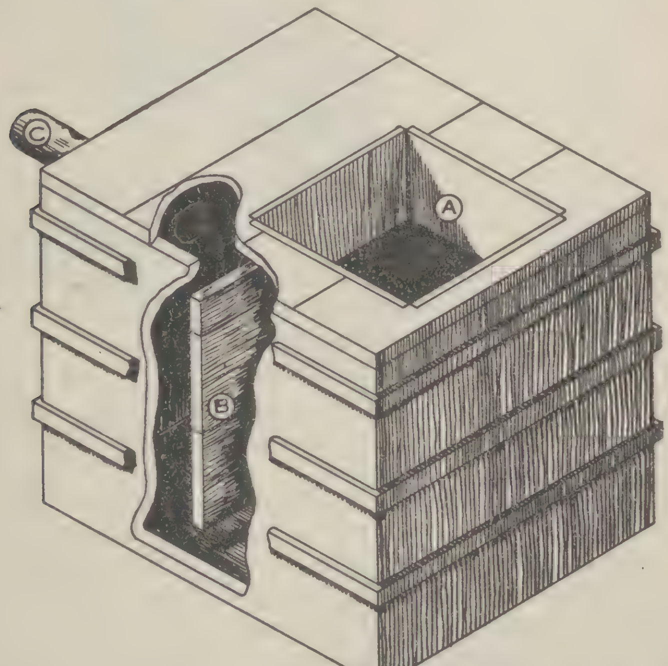


FIG. No. 246. Baffle grease trap. A—Strainer. B—Baffle. C—Outlet.

The filtering material should be removed at intervals of once or twice a week. If straw is used, it should be burned. Where the filtering material consists of ashes, charcoal, sand, coal, fine gravel, or other noninflammable substances, it should be burned to destroy the grease and other organic material. After burning, the material may be used again in the grease trap. If burning is impracticable, the used filtering material should be buried in the ground.

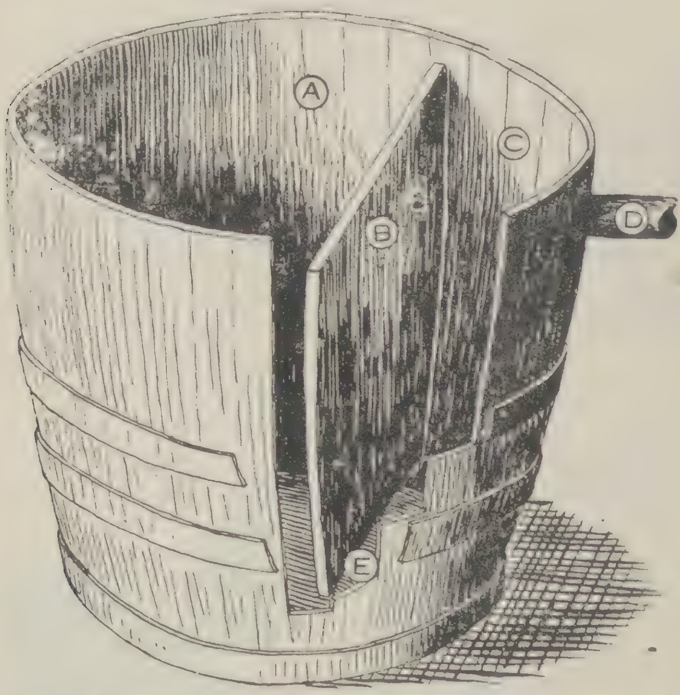


FIG. No. 247. Baffle grease trap made of a half barrel. A—Influent chamber into which the greasy fluid is emptied. B—Baffle. C—Effluent chamber. D—Outlet pipe. E—Space under baffle leading from the influent chamber to the effluent chamber.

The baffle grease trap (Figures No. 246 and 247). The baffle grease trap consists of a container which is divided by a hanging baffle into an influent and effluent chamber, the former having about twice the capacity of the latter. The container may be made of one-half of a wooden barrel, or it may consist of a rectangular tank or cask. The lower edge of the baffle is separated from the bottom of the container by a space

about one inch in width. The outlet leads from the effluent chamber and is placed from three to six inches or more below the upper edge of the container. It may consist of a short piece of one to two inch pipe or a wooden trough (Figures No. 247 and 248).

FIG. No. 248. Box grease trap with outlet trough.

The baffle grease trap is usually placed on the ground at the side of the soakage pit. The wooden, V-shaped trough or perforated pipe carries the effluent from the outlet to the center of the pit (Figures No. 248 and 249).

The coarse solids and debris should be removed from the water before it enters the influent chamber of the trap. A suitable strainer may be made from a galvanized pail or box which is inserted or built into the lid of the influent chamber. The strainer is filled about two-thirds full with loose straw, hay or grass which serves to catch and retain the coarser suspended solids. In lieu of a pail or box strainer, a single thickness of blanket cloth, or several layers of burlap, may be fastened over the influent chamber through which the water is strained.

When the grease trap is in use, both the influent and the effluent chambers are filled at all times with cool water. When the warm liquid wastes strike the cool water in the influent chamber, the grease rises to the surface and is prevented by the baffle from reaching the outlet to the soakage pit.

The retained grease should be skimmed from the surface of the water in the influent chamber at daily intervals.

The trap should be emptied and thoroughly cleaned at least once a week. The sediment removed from the trap should be burned or buried.

FIG. No. 249. Baffle grease trap with perforated pipe outlet discharging into soakage pit.

Soakage trenches. The ground water table may lie so close to the surface of the ground that a soakage pit will fill with water and the waste liquids will not be absorbed by the soil. In other instances, a rock stratum lying close to the surface of the ground may render the construction of a pit difficult or impracticable, or a tight clay stratum may prevent absorption. Under these conditions, waste water can be applied to the soil by means of a soakage trench and, unless the soil is water logged, will be absorbed into the top soil above the ground water table or the rock or clay stratum.

Construction of a soakage trench (Fig. No. 250). A typical soakage trench installation consists of a central pit, two feet square and one foot deep, from each corner of which a trench radiates outward for a distance of six feet. The trenches are

one foot deep where they leave the central pit but slope to a depth of eighteen inches at the other extremity. They are about one foot wide.

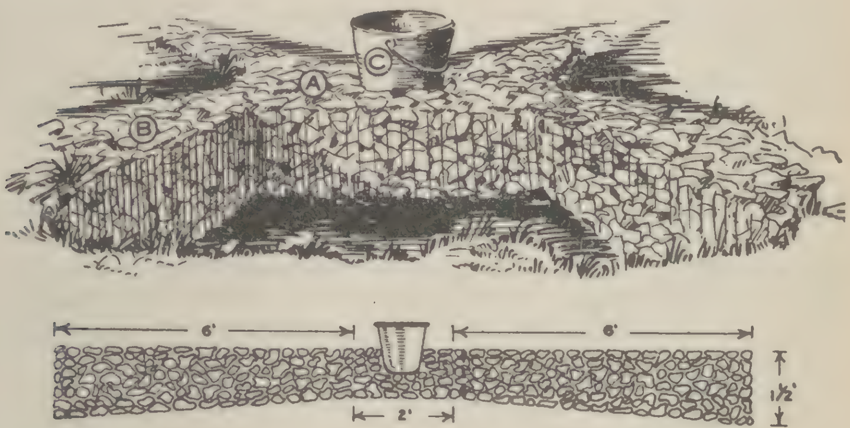


FIG. No. 250. Soakage trench. A—Central square area. B—Radiating lateral trenches. C—Pail grease trap.

The central pit and the trenches are filled to the surface with contact material, which may consist of stone, broken brick or concrete, flattened tin cans, broken bottles, etc. Broken stone from one-half to three inches in diameter should be used for contact material if obtainable.

A grease trap similar to that employed in a soakage pit should be installed in the central pit of the soakage trench.

The construction details and dimensions of a soakage trench installation vary with the height of the ground water table, the nature of the soil and the amount of waste water. A soakage trench having the dimensions described above has an absorbing surface approximately equal to that of a standard soakage pit (page 729). Owing to the relatively large surface area, ventilators are not necessary in a soakage trench.

Capacity, number and location of soakage pits and trenches. In loam, loam and sand, or other moderately loose soils where the ground water table is more than four feet below the surface of the ground, a properly operated soakage pit four feet square and four feet deep will dispose of all the waste water produced at the kitchen of a war strength infantry company. In localities where only tight soil is available, it may be necessary

to install two or more soakage pits, and, in any event, two soakage pits for each kitchen are desirable in order to insure thorough drainage and aerobic decomposition of the retained organic matter.

The soakage pit or trench is usually installed immediately adjacent to the company kitchen. Where two pits or trenches are employed, one is usually placed on either side of the kitchen. At times it may be necessary, in order to obtain the proper kind of soil, to locate the soakage pits at a distance from the kitchen.

Operation of soakage pits and trenches. The principles involved in the operation of a soakage pit or trench are the same as those concerned in the purification of sewage in a contact bed (page 686). A film is formed on the surface of the contact material which catches and retains the suspended and dissolved solids. In properly ventilated pits, this film supports large numbers of aerobic organisms and the organic matter is stabilized by oxidation.

In order for a soakage pit to function properly, the permeability of the soil must be such that the liquids are drained away so that there will be a rest period during which the pit contains little if any fluid and the atmospheric oxygen is in contact with the film on the contact material.

Usually, the waste water is poured into the soakage pit or trench as it is produced at the kitchen. Occasionally, where only one pit is available, it may be desirable to avoid applying water to the pit during a given period each day in order to provide a definite rest period. During this time the waste water is collected and held in containers. Where two pits are available they are used on alternate days.

If the soakage pits or trenches are located away from the kitchens, the water is collected in galvanized iron cans or other containers and hauled or carried by hand to the pits or trenches.

It is essential in the operation of a soakage pit or trench that all debris and as much grease as possible be prevented from reaching the contact material. Clogging, and the consequent failure of the pit to drain, is usually due to impervious soils, or to the clogging of the interstices of the soil with grease and organic matter. If the pit is allowed to rest for a period of from one to two weeks, the organic matter causing the clogging will undergo decomposition and the pit will again become serviceable.

In camps of long duration, clogging can sometimes be prevented by one-week rest periods at intervals of about a month.

Organic growths which sometimes appear in the contact material may be removed by the application of a ten per cent solution of calcium hypochlorite or caustic soda. The solution should be applied to the pit in five gallon doses on alternate days until the growths disappear. It may be desirable to loosen the surface of the contact material with a pick.

Disposal of waste water in bivouacs. In bivouacs, or in temporary camps of such short duration that the construction of soakage pits or trenches is not practicable, the waste water from the kitchens may be disposed of on the surface of the ground, or open trenches may be used to promote absorption by the soil. The trenches should be filled in with earth when they are no longer needed.

DISPOSAL OF BATH AND WASH WATER

Where sewers are available, the bath water and lavatory wastes are disposed of as sewage, but in the absence of sewerage, other means of disposal must be devised. Usually, the most practicable method of disposing of bath water locally is by means of soakage pits or trenches. These are constructed and operated in the same manner as those used for the disposal of liquid kitchen wastes, except that larger installations or a greater number may be necessary. A grease trap should be installed to remove the soap from the water before it reaches the contact material.

The soakage pits or trenches are located adjacent to the shower baths from which the water is conveyed to the pits or trenches by troughs, open trenches or pipes.

In the absence of soakage pits or trenches, the bath water may be disposed of for a short time in open trenches.

The soakage pits, soakage trenches, or open trenches should be at least 100 feet from any source of water used for drinking purposes. Improvised bathing facilities are further discussed on page 978.

Where no sewered lavatories are available, improvised facilities for the washing of hands and faces should be provided. Usually, a wash bench is installed at one end of each

company street. The troops should be furnished with canvas basins or similar equipment. The wash bench is drained into a soakage pit. A method of constructing and draining a wash bench is shown in Fig. No. 251.

FIG. No. 251. Wash bench showing center trough draining into a soakage pit.

CHAPTER XVII.

DISPOSAL OF MANURE

Accumulations of horse manure afford breeding places for the house fly and, unless controlled, will almost invariably produce large numbers of flies. Manure is, therefore, of sanitary significance, in that it affords a breeding place for flies which, after contact with human excreta, may become agents for the transmission of disease producing organisms to the food of man.

The quantity of manure produced varies somewhat with the method of caring for the animals. The average is about ten pounds per animal where animals are kept on a picket line without bedding. If the animals are stabled, the quantity of manure and bedding which must be disposed of will average from two to three cubic feet per animal per day, the weight depending on the character of the bedding and the amount of moisture.

Manure is a valuable fertilizer and should, whenever practicable, be used as such on the gardens and cultivated areas of the station or camp. If it is impracticable to use it on government land, it should be sold, or, if necessary, given away under contract. If it cannot be utilized as fertilizer, either on government or civilian owned land, it must be disposed of by other methods.

The procedures employed in the disposal of manure comprise the collection of the manure from picket lines, stables and corrals, its transportation to the place of disposal, and its final disposal. The methods of final disposal consist of disposal by contract, composting, spreading on fields as fertilizer, drying, and incineration.

Disposal by contract. The essential features of disposal of manure by contract are the same as those involved in the disposal of garbage by contract (page 738). The government enters into a contract with an individual or firm under the terms of which the contractor removes the manure from the military reservation and disposes of it elsewhere. The contractor may collect the manure at the picket lines or stables or it may be transferred to him at some designated place within or outside of the military reservation.

There are two principal factors to be considered in the disposal of manure by contract. First, the manure must be collected and transported in such a manner that fly breeding within the military reservation is prevented; second, the place of ultimate disposal should be far enough away that flies produced in the manure will not return to the camp or station, or if disposed of in the vicinity of the camp or station, measures should be taken by the contractor to control fly breeding. The contractor should be bonded to insure his observation of prescribed regulations relative to the methods to be employed by him in handling the manure.

In granting a contract for the disposal of manure, consideration should be given to the local civilian laws and regulations with regard to the disposal of manure in order that the rights and interests of civilian inhabitants will not be jeopardized.

Collection of manure. The manure should be collected daily, usually before 10 A. M. Prompt and thorough collection will minimize the infestation of the manure with the eggs of the house fly, and is particularly important if the manure is to be disposed of by any method other than incineration.

Collection should include sweeping the picket lines and stables in order that no small accumulations of manure will remain and afford breeding places for flies.

The manure is collected either by the personnel of the organization to which the animals belong, by Quartermaster Corps troops or employees, or by the contractor or his employees. If collected by military personnel, it may be transported in army vehicles to the place of ultimate disposal or, if it is to be disposed of by contract, to a transfer station or point for transfer to the vehicles of the contractor.

Regulations should be promulgated and enforced to prevent spillage of manure from vehicles at the time of loading or while enroute from the place of collection to the place of disposal.

At large camps, such as divisional camps, the manure transfer station is usually a railroad siding where the manure is transferred from Government trucks or wagons to the railroad cars of the contractor. A concrete loading platform should be provided which is so constructed that trucks can be driven alongside of the cars. All spilled manure should be immediately swept up and thrown upon the car. The space around the platform should be paved and drained so that it can be cleaned with a hose.

In the smaller camps and stations, the manure may be placed in a compost pile, from which the contractor transfers it to his fields. Or the manure may be transported to a compost pile built and maintained by the contractor and located on or off the military reservation. More rarely, the manure is transported to some selected point where it is transferred from government trucks or wagons to the trucks or wagons of the contractor. When the latter method is used, it is difficult to prevent spillage during transfer, with consequent pollution of the soil and fly breeding.

Disposal by composting. When manure is closely packed in a heap, or in a bin or other container, the heat generated by fermentation will kill the fly larvae. This method is known as composting, or close packing, and provides a means of storing manure under fly free conditions until it can be used as fertilizer on fields or gardens. In composted manure, a temperature of from 140°F. to 160°F. is reached at depths of more than eight inches to one foot below the surface, while a temperature of 115°F. is sufficient to kill house fly larvae within a few minutes (page 788).

The manure in a properly constructed and maintained compost pile will remain free from fly larvae indefinitely. Eventually, fermentation ceases, the organic matter becomes mineralized, the soluble constituents drain away, and the conditions necessary for fly breeding are no longer present. As the house fly breeds most readily in fresh manure, the untreated surface of a compost pile under average conditions will not afford a breeding place for the house fly after a lapse of

two months, and, usually, breeding is not active after one month. Fermentation continues with decreasing intensity in the interior of the pile for from three to five months.

The manure is usually infested with house fly eggs when placed in a compost pile and in the absence of control measures, such as the use of larvacides, or repacking of the outer layers, larvae will develop and further infestation will occur in the cooler outer layers of the pile. When the larvae mature, they migrate to some dry place beyond the limits of the pile, or to the dryer edges of the pile to pupate. The larger number migrate between the sixth and tenth day after the manure is placed in the compost pile but, if not interfered with, migration continues until about the fourth week. If composted manure is used as a fertilizer before fermentation ceases, it may, if spread on the ground in a moist condition, again become a breeding place for flies if they gain access to it before it is desiccated by the sun and wind or is plowed under.

The fermentation which occurs in a compost pile reduces the fertilizing value of the manure to some extent through loss of ammonia and gaseous nitrogen, but such loss is relatively slight during the first few weeks.

Construction and maintenance of the compost pile. The ground upon which a compost pile is to be built should be prepared by removing the grass and tamping down the loose top soil to form a compact surface. If practicable, the surface of the ground should then be well sprayed with crude oil or waste motor oil. The area upon which the pile is to be placed may be ditched as described below.

Compost piles vary in size from those which can be conveniently constructed by one man to piles which will provide space for and support a light truck or wagon roadway. The typical pile for a station or for small camps is from five to ten feet wide at the base and from three to six feet high, the length depending on the quantity of the manure to be composted (Fig. No. 252).

The manure collected each day is placed on the compost pile and firmly packed. Fermentation within the tightly packed mass will either kill all the fly larvae or drive them from the depths of the pile to within a few inches of the surface. Usually, no larvae will exist at a depth of more than four to six inches.

FIG. No. 252. Manure compost pile with ditches for the control of migrating larvae. (Courtesy of the Medical Field Service School, Carlisle Barracks, Pa.).

As the pile extends, it should be fenced on both sides and at one end so that the fresh manure will be added only at one end of the pile. The sides of the pile should be as nearly vertical as practicable with only sufficient slope to facilitate thorough packing.

The method of constructing a compost pile, as described above, is susceptible of many modifications. At a permanent station or camp where a given area is to be used for composting manure for an indefinite period of time, concrete bases or platforms may be installed. A concrete base will decrease pupation of flies under the outer borders of the pile, facilitate drainage and thus prevent the ground under the pile from becoming soaked with liquid, and permit of proper cleaning after the manure has been removed. Posts and rails of pipe may be used to hold the sides of the pile in place.

As the success of composting in the prevention of fly breeding depends on the generation of heat, active fermentation should be promoted by maintaining the manure in a moist condition. If necessary, the pile may be moistened at daily intervals with water from a hose or buckets.

The mature larvae endeavor to leave the moist environment of the manure to pupate in a dry place. Consequently, pupation can be controlled to a considerable extent by ditching, or by stripping free of all vegetation an area from two to four feet wide completely around the pile and spraying the surface with crude oil or waste motor oil at weekly intervals.

Ditching. The success of composting as a fly control measure can be materially increased by installing a ditch or trench along each side of the pile and across the end at which the pile was begun. The inner edge of the ditch should be immediately adjacent to or directly under the border of the compost pile. As the pile is extended the ditches are likewise extended along the sides of the pile. When the pile is finished the ditch is extended across the finished end, thus completely surrounding the pile. The ditch should be from six inches to one foot in depth, and should have vertical sides. The bottom of the ditch and the lower three or four inches of the ditch walls should be lined with waterproof material such as asphaltum or concrete. If the soil contains a considerable proportion of clay, the bottom of the ditch may be made sufficiently water tight by tamping. The bottom of the ditch should be covered to a depth of one to three inches with light crude oil if a supply is available. Waste motor oil may be used for this purpose. It is as effective as crude oil and much cheaper. Water can be used if oil cannot be obtained. The ditch serves as a larvae trap to catch and destroy the larvae as they migrate from the compost pile.

The bottom of the ditch should be approximately level so that all the oil will not drain into one part of the ditch. The ditch may be divided into sections by low transverse walls or dams in order to retain the oil in various portions of the ditch.

Permanent ditches may be installed where the same area is to be used continuously for compost piles. These ditches should be divided into sections so that only that portion of the ditch which borders the area being used need be filled with oil while the pile is being constructed.

Control of fly breeding at the surface of the compost pile. While the prompt and thorough collection of horse manure will reduce infestation with fly eggs, absolute prevention of infestation is difficult to accomplish. As a consequence, the eggs will hatch and larvae develop where the conditions in the compost pile are favorable, as they frequently are immediately

below the surface. As the heat generated by the fermentation will not kill the fly larvae in the outer layers of the pile, measures should be taken to destroy them or to prevent their further development.

In the case of the larger compost pile, a six inch layer of the manure may be removed from the sides and buried in the center of the pile where the heat is sufficient to kill the larvae. If this method is used, the sides should be stripped at intervals of not more than three days.

Many substances may be applied to composted manure to kill the larvae developing in the outer layers of the pile. Crude oil, waste motor oil, kerosene, or one to three per cent solutions of cresol are all effective and cheap larvacides, but if used in quantity they impair the fertilizing value of the manure. If the manure is not to be used as a fertilizer, a two per cent solution of cresol will usually prove to be the best larvacide for treating composted manure. Where the manure is to be used subsequently for fertilizer, the compounds most commonly employed as larvacides are borax, hellebore and iron sulphate.

The borax solution is prepared by dissolving one pound of the powdered chemical in four gallons of water. This solution is applied as a spray to the surface of the compost pile at the rate of one quart per square foot of surface. The powdered borax may be used by dusting on the surface of the pile and thoroughly wetting. It should be applied in quantities of about one ounce per square foot.

Borax kills both the eggs and the larvae of the house fly. It does not impair the fertilizing value of the manure but is injurious to certain plants when used in large quantities. However, if not more than fifteen tons of the treated manure from the sides of the compost pile are applied per acre at one time, no appreciable damage will result.

Hellebore is applied as an aqueous extract of the powder. The extract is made by mixing one pound of the powder in twenty gallons of water and allowing it to stand for twenty-four hours before use. It is applied as a spray at the rate of one gallon of the extract to each square foot of the surface of the pile.

Iron sulphate is used as a solution of two pounds of the chemical in one gallon of water. It is sprayed onto the sur-

face of the pile at the rate of about one-half gallon per square foot.

Larvacides should be applied at intervals of at least once, and preferably twice, a week until the manure is removed for use as fertilizer or, if it remains *in situ,* until fly breeding ceases in the outer layer of the pile. An ample number of fly traps should be placed around the compost piles (page 795).

Location of compost piles. The compost pile should be located where it will not be an unsightly nuisance. If fly breeding cannot be completely controlled, the pile should be from one-half to one mile from the barracks or tents, latrines or kitchens.

The compost bin. Manure may be composted by being placed in a concrete or wooden bin. The bin should be made of concrete wherever practicable, as it is difficult to render a wooden bin sufficiently tight to prevent the escape of some of the larvae.

A concrete trench three or four inches deep may be built across the front of the bin to trap the migrating larvae that escape through the crevices around the door. This trench should be kept filled to a depth of one inch or more with crude oil or waste motor oil. If the bins are open at the top, the surface of the manure should be sprayed with a larvacide.

The manure should remain in the bin until the development and migration of the fly larvae cease. This usually occurs in from two weeks to one month, depending on the extent to which the manure is infested prior to being placed in the bin and the degree to which it is protected from flies while in the bin.

From 0.5 to 1 cubic foot of bin space will be required per animal per day.

The manure should be firmly packed into the bin. All manure scattered on the ground should be carefully swept up and placed in the bin. If the manure tends to become dry, it should be wetted at daily intervals to promote fermentation. If wooden bins are used, they should be inspected from time to time for cracks and crevices which will permit the larvae to escape. A number of fly traps should be placed in and around compost bins.

The walls of the compost bin render it more efficient than the compost pile in preventing migration of the larvae. Com-

post bins can be installed in or near stables and thus decrease the labor required for the collection of the manure. While the nature and the extent of the construction required for the installation of compost bins reduce their usefulness in large camps, they can in many instances be employed to an advantage at smaller stations.

Disposal of manure as fertilizer. Either freshly collected or composted manure may be disposed of on the soil as fertilizer. If climatic conditions permit, it should be spread in a thin layer so that it will dry rapidly and thus prevent the further development of fly eggs or larvae. Composted manure should be free from eggs and larvae when applied to the soil, but fresh manure will probably be infested to some extent before it is taken from the stables or picket lines. In any event, if the manure lies exposed on the fields under conditions which promote fermentation and preclude immediate desiccation, it will soon become a breeding place for house flies.

The manure to be spread as fertilizer should be as finely divided as practicable and the accumulation of large masses which would dry slowly should be avoided.

If conditions are such that the manure will not dry on the surface of the ground, it should be plowed under as soon as practicable after being spread. Plowing under of uninfested composted manure will prevent fly breeding. If the manure, either composted or fresh, contains partially developed larvae, some of them will continue their development after being plowed under, particularly if they are contained in masses of manure. Wherever practicable, only composted manure should be used as fertilizer.

Disposal by drying. Manure may be rendered free from fly larvae and further infestation prevented by thorough drying to remove the moisture which is essential for the development of the immature forms. As air drying is the only practicable procedure by which this can be accomplished, the disposal of manure by drying is feasible only in dry climates.

The manure is spread on the ground in a thin layer not over one to two inches thick. The drying area required varies from four to twelve square feet per animal depending on the thoroughness of the collection and on the amount of bedding, if any, that is used. An area at least 25 feet square is usually

required to dry the manure produced in one day by 100 animals. As from four days to a week are usually required to dry the manure, from four to seven areas are selected, each of which is of sufficient size to receive the manure produced in one day. The ground should be smoothed and packed down before each application of manure. All lumps and masses should be broken up when the manure is placed on the drying area and it should be raked each day. When dry, the manure is removed and the drying area prepared for another application.

The dried manure may be used for filling low areas, it may be stored in stacks for future use, or it can be burned. If the manure becomes wet soon after having been dried, it may afford a breeding place for house flies.

Incineration of manure. While it is desirable that manure be utilized as fertilizer wherever practicable, it frequently happens in the military service that conditions will preclude this method of disposal. Under such circumstances, incineration of the manure is the best method of obtaining effective fly control with a minimum of labor and expense.

Manure may be incinerated in windrows or stacks or in incinerators constructed especially for that purpose.

Incineration in windrows or stacks. Fresh manure may be dumped on the ground in long windrows, sprayed with oil and burned immediately. Usually, if conditions permit, the manure is dried for three or four days prior to burning when, if it contains considerable bedding, it can be burned without the aid of oil. Dried manure may be placed in small stacks and burned with or without the use of oil. Care should be taken that all manure scattered from the windows or stacks is collected and burned.

Manure incinerators. The principles involved in the destruction of manure by incineration are the same as those that pertain to the incineration of garbage. However, as manure is more voluminous and burns more readily than garbage, open incinerators are usually employed (page 746).

The grid manure incinerator usually consists of a grate of railway rails laid on brick or concrete piers as shown in Fig. No. 253. The rails may be placed over an open pit instead of on piers (Fig. No. 254).

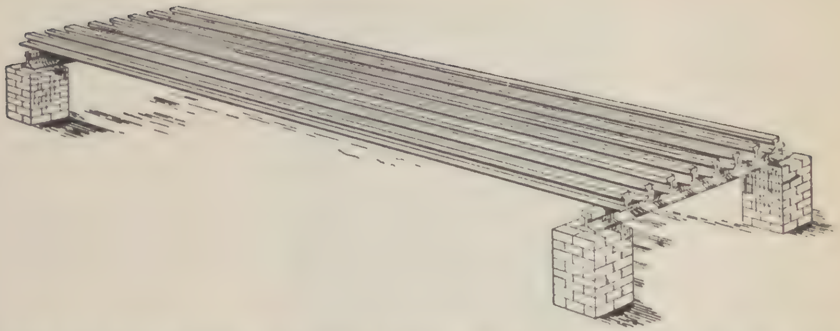


FIG. No. 253. Manure incinerator consisting of grid made of railroad rails elevated on brick piers.

FIG. No. 254. Grid incinerator, consisting of railroad rails laid over an open pit.

The rock pile incinerator may be used for burning manure (page 752).

Location of incinerators. Burning manure produces malodorous gases which create a nuisance if they reach the vicinity of human habitations. Manure incinerators, or the area where the manure is burned in windrows or stacks, should be located at least 500 yards, and preferably from one-half to one mile, from barracks or tents occupied by troops.

Operation of incinerators. As a rule, a certain amount of fuel, either wood or crude oil, must be used to burn fresh manure in an incinerator. Drying the manure for three or four days prior to burning will reduce the amount of fuel required.

Care should be exercised to prevent trampling the manure into the soil around the incinerators and thus providing an opportunity for fly larvae to develop.

CHAPTER XVIII.

FLY CONTROL

The habits and characteristics of the house fly, *Musca domestica*, are such that it may become an important factor in the spread of intestinal diseases. The fly serves as an agent by which the excreta of a person ill with an intestinal disease, or of one who is a carrier of the causative organisms, may be transmitted to the food of an individual who is susceptible to the infection in question. Consequently, the principal object of all fly control measures is to prevent contact between the food of the troops and flies which may be carriers of pathogenic organisms.

As the control of house flies is essentially a measure for the protection of the health of the troops, the Medical Department is responsible for supervisory and inspectorial activities pertaining to fly control procedures. The Quartermaster Corps is normally responsible for the supply of all material and labor required for the operation of installations in which fly control is a factor, and the execution of fly control procedures where such installations and procedures pertain to two or more units. Organizations are responsible for the execution of fly control procedures which are organizational activities.

HABITS AND CHARACTERISTICS OF THE HOUSE FLY

The house fly develops by complete metamorphosis. The egg, larval, pupal, and adult stages each require certain definite environmental conditions for their development.

The egg stage. The eggs of the house fly are oval, white, glistening bodies about one millimeter in length. They are deposited in clusters or masses on or in moist organic material which will furnish food for the larvae and provide the necessary warmth (Fig. No. 255).

FIG. No. 255. Eggs of the house fly (*Greatly enlarged*) (Courtesy of the Army Medical Museum).

The individual fly deposits from 100 to 150 eggs at one time and will normally lay from two to four batches during her lifetime. Under exceptionally favorable conditions, as many as twenty batches of eggs may be laid by one fly, or a total of over 2000 eggs. The eggs are deposited in the cracks and crevices of the breeding material, usually below the surface where the heat generated by the fermentation of organic substances will facilitate hatching and the moisture will prevent desiccation.

The length of the egg stage is usually about 12 hours, but given the proper amount of moisture, it varies widely with the temperature. The eggs hatch in about eight hours at a temperature of between 85°F. and 90°F.; in about 24 hours when the temperature is between 60°F. and 68°F., and in from two to three days at a temperature of 40°F.

The larval stage. The mature larvae of the house fly (maggots) are cylindrical, grayish, or creamy white, segmented, worm-like creatures about 12 mm. in length. The newly hatched larva is about twice the length of the egg. It is highly motile and burrows into the fermenting masses in which the eggs were deposited. The fly larvae grow rapidly and feed upon the vegetable organic matter which surrounds them. They develop by successive moults, reaching maturity, under average conditions, in from four to five days, although the larval period may be much prolonged by cold, or lack of moisture or food.

The optimum temperature for the development of fly larvae is about 90°F. They are quickly killed by a temperature of 115°F., or if the material in which they are growing is wet, by a temperature as low as 108°F. They are also sensitive to the gases produced by fermentation.

FIG. No. 256. Pupa and larva of the house fly. (*Enlarged*). A—Pupa. B—Larva. (Courtesy of the Army Medical Museum).

When maturity is attained, the larva enters upon the migratory phase of its existence and leaves the moist, warm environment in which it has developed in order that it may pass the pupal stage in a dryer and cooler place. At times, it will enter the pupal stage at the edge of the fermenting material or will burrow into the earth beneath. It may crawl for some distance to pupate in loose soil or under rocks or boards.

The pupal stage. When the mature larva enters the pupal or chrysalis stage, the body contracts and thickens and the outer surface hardens to form the pupal case. The pupa is dark in color and about 6 mm. in length. It is immobile, and the food consumed during the larval stage suffices for the

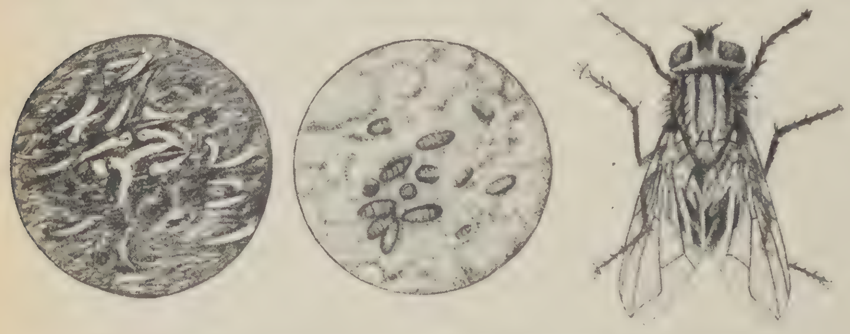


FIG. No. 257. Larval, pupal and adult stages of the house fly.

pupal stage. Under average conditions, the pupal stage continues for from three to ten days, but may be much prolonged in an adverse environment.

The adult fly. When the adult fly emerges from the puparium it crawls upward through the loose soil, manure, or other materials, to the surface. As soon as the wings harden it is ready for flight.

The female house fly reaches sexual maturity and oviposition begins in from two and one-half to twenty days subsequent to emergence from the puparium. The pre-oviposition period may be prolonged by low atmospheric temperature and low humidity. Under suitable environmental conditions, the developmental period from egg to adult may be as short as seven days and, consequently, any material in which the immature forms will develop may produce flies if allowed to remain uncontrolled for longer than one week.

The house fly averages one-quarter of an inch in length and does not grow after hatching from the pupa. The smaller flies sometimes seen around or in inhabited buildings and which closely resemble the house fly, except for size, are usually *Fannia canicularis* or *Fannia scalaris,* also known as the "lesser house fly" or "latrine fly". They are not, as is frequently thought to be the case, partially grown house flies. These flies, like the house fly, breed in excreta and fermenting vegetable wastes. The larvae are distinguishable from those of the house fly by the presence of spines. The adult flies do not alight on food as frequently as the house fly and for this reason are less dangerous carriers of disease-producing organisms. The procedures employed to control the house fly are also effective against *F. canicularis* and *F. scalaris.*

The biting fly which is most frequently mistaken for the house fly is the stable fly, *Stomoxys calcitrans.* The stable fly breeds normally in straw, but will breed in horse manure that is mixed with straw. It does not frequent latrines and is not a factor in the transmission of disease to man.

The bottle flies known as *blue bottle flies* (*Calliphora vomitoria* and *C. erythrocephala*) and *green bottle flies* (*Lucilia caesar*) breed normally in fresh or decayed flesh. The large black blow fly, *Phormia regina,* breeds in animal wastes and garbage. Blow flies, or bottle flies, are occasionally found in large numbers in and around latrines and the green bottle fly and the black

FIG. No. 258. Adult house fly, *Musca domestica*. (Photograph). (Courtesy of Lieut. Colonel James P. Crawford, Medical Corps, United States Army, Chief, Division of Entomology, Army Medical School, Washington, D. C.)

blow fly may breed in human excrement. These flies may serve to transmit disease-producing organisms from their breeding places or from latrines to food in kitchens and messes.

Feeding habits of the house fly. The house fly is a non-bloodsucking insect, the proboscis being adapted for sucking or absorption of liquids and not for penetration of the skin. It cannot ingest particles larger than 0.045 mm. in diameter. Dry food substances, such as sugar, are liquefied by regurgitated liquids prior to ingestion. The regurgitated liquid forms

the "vomit drop", and is frequently partially re-ingested. The house fly is attracted to food principally by odor, rather than by sight. The sense of smell is highly developed as compared with the acuteness of vision.

The fly is a persistent and greedy feeder, the ingested food passing to the crop, or esophageal diverticulum, which serves as a food reservoir. The regurgitation of ingested food, or vomit drop, from the esophageal diverticulum, and the excretion of feces occur at frequent intervals while feeding and are important factors in the contamination of food with pathogenic organisms derived from human excreta.

Range of flight. The house fly does not migrate far from the place of emergence, provided food and breeding places are accessible nearby. Normally, under these conditions, the range of flight will not exceed from 500 to 1000 yards, and for the larger number not more than 200 to 300 yards. If food is absent from the vicinity of the breeding place, as may happen when infested manure is hauled into fields, a large proportion of the flies which hatch out will migrate, under favorable circumstances, for as far as one mile in search of food. Much longer migrations have been reported and flies may be carried by the wind or drift with air currents for long distances.

Length of life and seasonal variations. While experimentally, house flies have been kept alive for as long as 70 days, the average life span of the adult fly is about one month. In the United States, breeding begins in May in the northern states and in April or March in the southern states. Generally, the number of house flies is the greatest in August and September and rapidly decreases with the advent of cooler weather. In the fall of the year, many flies are killed by a parasitic disease caused by a fungus, *Empusa muscae.* House flies are rendered inactive by cold and are killed by exposure to a temperature of between 10°F. and 15°F.

The house fly does not survive the winter months as an adult but hibernates in suitable breeding places in the larval or pupal form. The larvae mature slowly and pupate irregularly. Frequently, there is a prolonged pupal stage. The warm weather of early spring will cause the pupae to develop and the adult flies to emerge. Mild weather for a few days in midwinter will fre-

quently be accompanied by the appearance of house flies which are attracted by warmth to inhabited buildings.

Continuous breeding may occur throughout the winter in heated buildings or warm stables, provided food for the adult flies and breeding places are present.

The transmission of organisms by the house fly. The adult house fly comes into contact with human excreta while feeding on the soluble constituents of the fecal material, during the act of laying her eggs in the excreta, or at the time of emergence from the puparium. Liquid portions or solid particles of the excreta, which may contain pathogenic organisms, adhere to the external surfaces of the body and appendages of the fly. When the fly alights on food in the kitchens and mess halls, this infected material may be rubbed off and deposited on the food.

The fly ingests human excreta while feeding in latrines or elsewhere and then regurgitates and excretes droplets of this fecal matter on the food of man. Many of the pathogenic organisms which are ingested by the fly larva during its development in human excreta remain in the alimentary tract of the insect through pupation and are excreted by the adult fly, possibly on the food of man.

Organisms transmitted. The house fly is capable of transporting, either within the alimentary tract or on the external surfaces of the body, any of the pathogenic bacteria that cause intestinal disease in man. Also, the house fly can transfer from excreta to food the infective forms of many of the protozoa, such as the cysts of *Endameba histolytica,* and the eggs of helminths that do not require an intermediate host, such as *Ascaris lumbricoides,* or *Hymenolepis nana.*

BREEDING PLACES

A breeding place for house flies must provide moisture, warmth and food for the larvae. The temperature must be less than 115°F., moisture must be present in sufficient amounts to promote fermentation of the breeding material and to prevent desiccation of the eggs or larvae, and food in a finely divided or soluble form must be accessible to the larvae. The breeding material must be alkaline, as small amounts of acid will inhibit the development of the larvae.

The house fly will breed in a variety of fermenting vegetable wastes, but selects by preference loosely packed or small accumulations of fresh horse manure. Next in importance to horse manure as breeding materials and, other factors being equal, in the order named, are human excreta, the manure produced by domestic animals other than the horse, garbage, and other organic wastes such as decaying vegetables and fruits. Frequently, rubbish dumps contain organic wastes which afford breeding material for flies. The liquid wastes spilled on the ground around garbage cans and stands may ferment and convert the soil into a breeding place for flies.

Small deposits or masses of excreta, human or animal, or of vegetable wastes lying on the surface of the ground, if the proper amount of moisture is present, will furnish breeding places for large numbers of flies.

CONTROL PROCEDURES

Fly control procedures are designed first, to eradicate flies by modifying local conditions so that they will be unfavorable for fly breeding and by the destruction of the adults; second, by protecting food from flies; and third, by disposing of the excreta, from which flies obtain pathogenic organisms, so that it will be inaccessible to them. As in all insect control procedures, the principles involved in the control of house flies are based on habits and characteristics which render them vulnerable to certain specific measures.

The principal habits and characteristics of the house fly which are to be considered in the formulation and execution of control procedures are:

a. The preference for horse manure as breeding material and the tendency to breed freely in horse and other animal manure, human excreta, and fermenting vegetable wastes.

b. The necessity for moisture, warmth and soluble food for the normal development of the larvae.

c. The susceptibility of the larvae to temperature of from 110° to 115°F.

d. The tendency of the mature larvae to migrate from the breeding material prior to pupation.

e. The development of the pupa at or beyond the borders of the mass of breeding material.

f. The ability of the larvae and the adult insect to crawl through loose manure or earth.

g. The attraction of adult flies to food by odor.

h. The tendency of flies to fly towards light.

i. The tendency of flies to rest on vertical surfaces or hanging objects.

In the temperate zone, it is essential that fly control measures be inaugurated prior to or at the beginning of the fly breeding season and continued consistently and unremittingly until breeding is stopped by cold weather. In tropical or semi-tropical localities, where the climatic conditions permit fly breeding throughout the year, control measures must be continuously applied.

The continuous application of measures which will prevent fly breeding are, as a rule, less expensive in labor and funds and much more effective than the sporadic employment of fly control procedures after large numbers of flies have been produced. The measures designed to control breeding are far more effective in the ultimate prevention of flies than those employed for the purpose of destroying the adult insect.

Control of breeding. The breeding of house flies is controlled either by the elimination of breeding material or the establishment of conditions which prevent oviposition or inhibit the development of the larvae. The essential features concerned in the control of fly breeding in human excreta, garbage and manure, are considered in Chapter XV, Chapter XVI, and Chapter XVII, respectively, in connection with the disposal of these wastes.

Destruction of adult flies. Adult flies may be destroyed by the use of traps, fly paper; poison sprays and swatting, but these measures are seldom more than temporarily effective in reducing the total number of flies in a station or camp, unless they are employed in conjunction with the control of fly breeding. However, even in the presence of uncontrolled breeding, the destruction of adult flies in and around kitchens and mess halls is a valuable procedure, as it serves to remove those flies which are most apt, because of their presence in these places, to contaminate the food of the troops.

Fly trapping. The success of fly trapping in effecting an appreciable reduction in the number of flies depends upon efficient and constant supervision, and the use of properly constructed traps and suitable baits. In the capture of house flies in traps, advantage is taken of the tendency of adult insects to fly towards the light and their attraction to food by odor, rather than by sight.

Fly traps vary in design and size, but all consist of two main parts, the bait chamber and the trap chamber. The bait chamber is the lower and darker part of the trap into which the flies are enticed by the odor of the bait. The trap chamber is the upper and lighter part and is connected with the bait chamber by an aperture through which the flies crawl towards the light after

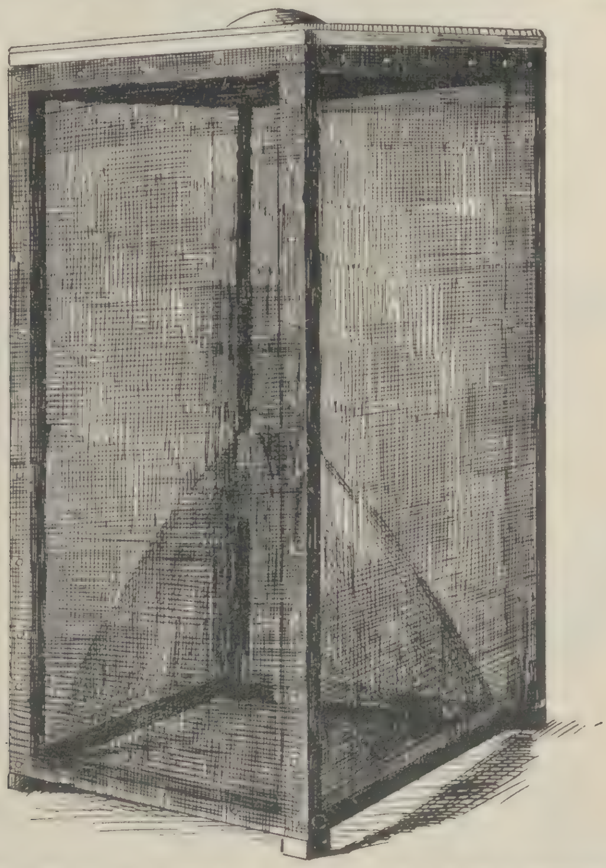


FIG. No. 259. Square fly trap with removable top and pyramidal shaped bait chamber.

having fed on the bait. The tendency of the house fly to fly or crawl towards the light prevents it from passing back into the bait chamber and thus escaping from the trap.

The square fly trap. The square fly trap is made as shown in Fig. No. 259. It is usually from 12 to 18 inches square and from 18 to 24 inches in height. The corner uprights and the connecting lateral strips are usually one inch thick and one and one-half inches wide and are made of clear wood. The framework is covered with 14 to the inch mesh metal screening which is tacked firmly to the corner posts and connecting strips. The lid consists of a frame covered with screening and fits down over the edges of the top of the trap.

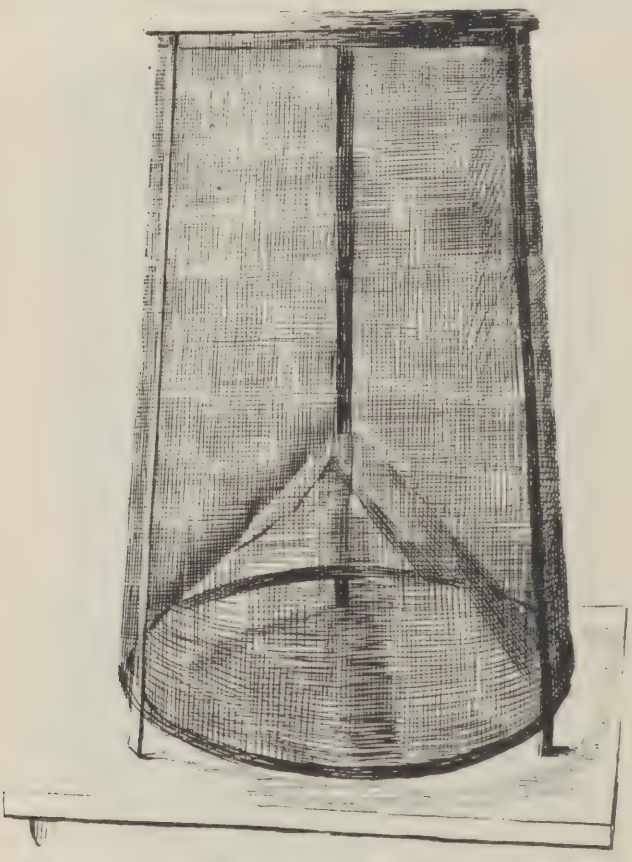


FIG. No. 260. Round fly trap with conical shaped bait chamber and removable top, or lid.

Inside the trap is a pyramidal or conical bait chamber made of screening which is fastened at the base to the lower edges of the trap and terminates in an apex which is from 10 to 14 inches above the bottom of the trap. At the apex is a hole ½ inch in diameter, through which the flies in crawling towards the light pass into the trap chamber. The corner uprights extend below the lower edge of the trap for about one inch to form the supports for the trap.

The round trap (Fig. No. 260). The round trap is similar to the square trap, except as to shape. The framework may be made of two barrel or keg hoops connected with lath uprights, or by wooden strips one inch thick and 1½ inches wide. Where camps or buildings are being constructed, nail keg hoops are at times available for this purpose. The framework may be made of metal, such as strap iron, but it is difficult to attach the screening to metal. The lid, or top, is usually solid, but may be made of screening.

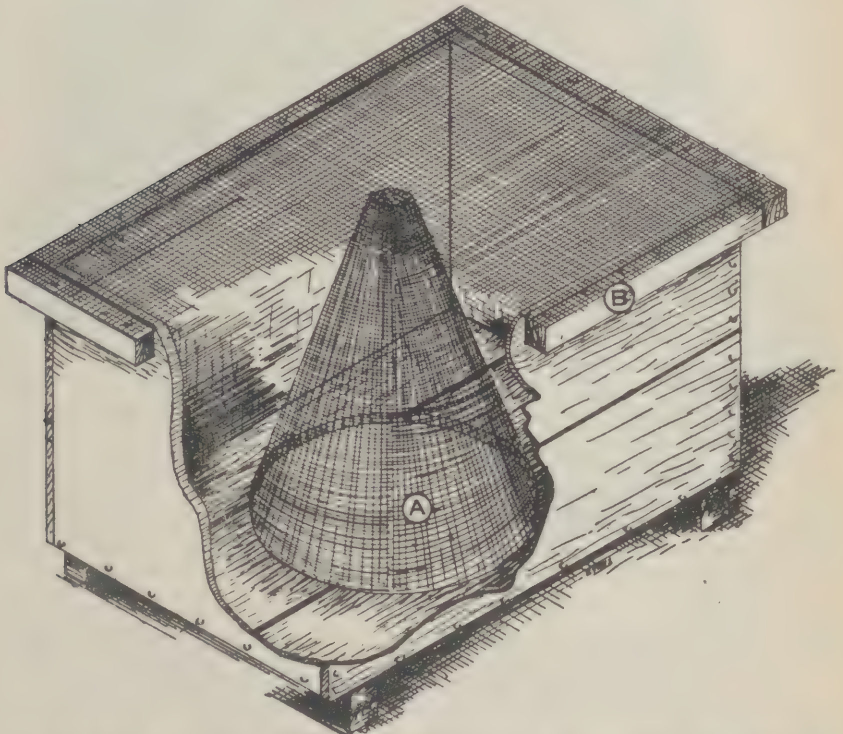


FIG. No. 261. Fly trap constructed of packing box. Corner cut away to show method of installing cone.

The box fly trap (Fig. No. 261). The box fly trap is made in the same manner as the square trap, except that the sides are made of boards instead of screening. It may be made of packing boxes, such as those in which canned milk or tomatoes are shipped, by inserting a cone made of screening into the bottom of the box and covering the box with a lid made of screening.

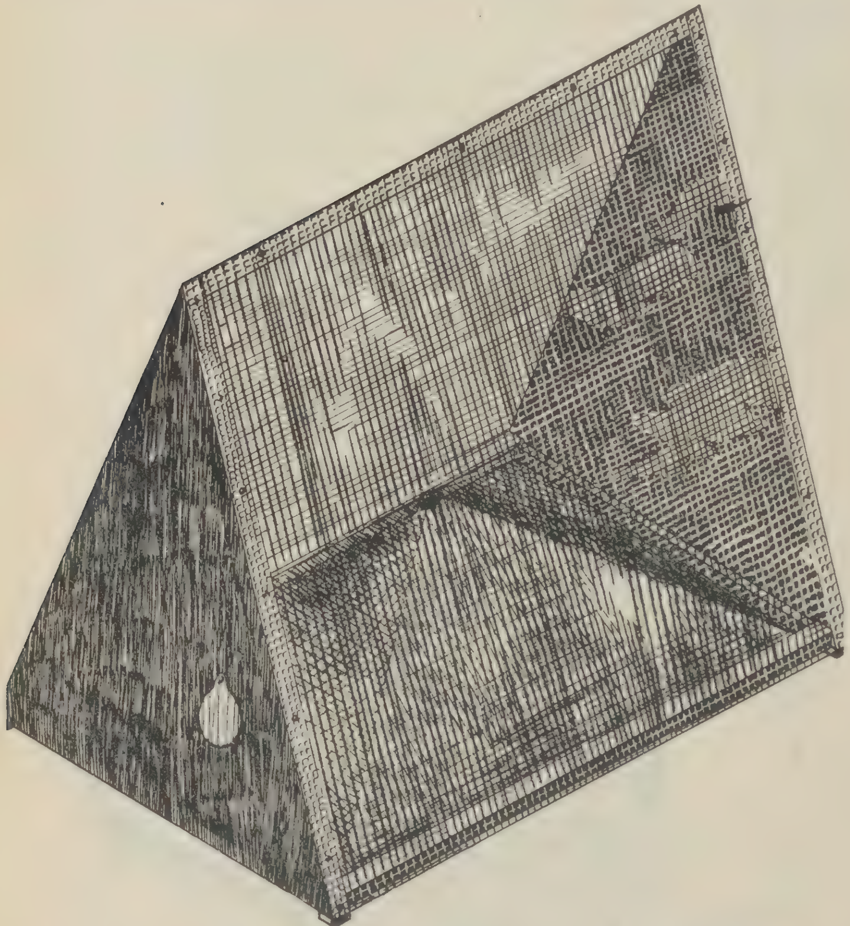


FIG. No. 262. Triangular fly trap with cone shaped bait chamber. Single opening at apex of cone leading into trap chamber. The small tin disk covers an opening through which flies may be removed from the trap chamber.

The triangular fly trap. The triangular fly trap is constructed as shown in Fig. No. 262. Triangular traps may vary considerably in size but they should be not less than 12 inches high and 12 inches long. The smaller traps are not as effective as those which are from 12 to 18 inches in height. If the traps are less than 12 inches long, the ends exclude much of the light necessary to attract the flies into the trap chamber.

The triangular ends are sawed from one inch rough lumber. The ends of the trap are connected by three wooden strips one inch square (Fig. No. 262). The trap is covered with a continuous piece of 14 to the inch mesh metal screening, which beginning at one side of the base is stretched over the apex to the base on the other side. The bait chamber is made of screening in the shape of a cone or pyramid, the lower edges of which are fastened to the bottom edges of the sides and ends of the trap. At the apex of the bait chamber is a hole about one-half inch in diameter. The bait chamber is usually about eight inches high in a trap which is 18 inches in height. A hole from one to two inches in diameter is cut in one of the ends near the bottom of the trap chamber through which the dead flies can be removed from the trap (page 803). It is covered with a tin flap fastened at the top with a single nail so that it will swing to one side.

A block of wood about one inch thick is nailed to the bottom of the trap at each corner in order to raise it sufficiently to permit the flies to reach the bait.

Comparative effectiveness of square, round, triangular and box traps. The square and round traps are more effective than the triangular trap, principally because the light enters the trap chamber from all sides. They are, however, more difficult to construct than the triangular trap. Exposure to the weather, and the handling to which fly traps are subjected, will cause the square and round traps to warp and become unserviceable much sooner than the triangular traps.

Despite the fact that the triangular trap is somewhat less effective as a single unit than the square or round trap, it will, as a rule, prove more practical for use in camps and large stations than either of the latter because of the comparative ease and rapidity with which it can be constructed in large numbers, the availability of material, and greater serviceability.

The box trap will not catch as many flies as the square or round trap, largely because the wooden sides exclude the light

from the trap chamber. The box trap is, however, more durable than any of the others and if packing boxes are available, it can be more quickly and cheaply constructed.

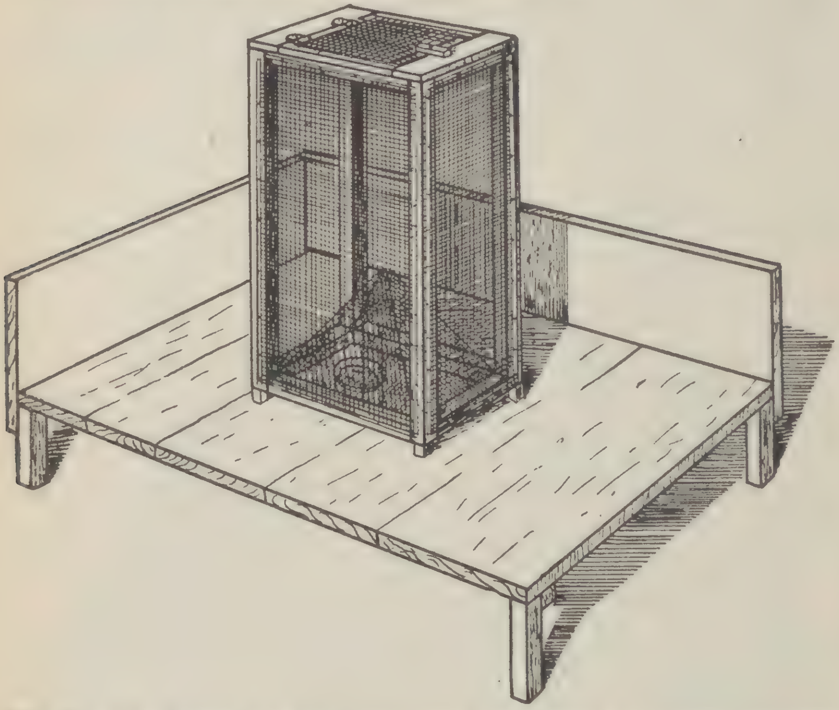


FIG. No. 263. Square fly trap with board windshield to protect the trap from the wind.

Fly trap stands. The efficiency of the fly traps is increased if they are elevated above the ground on stands, or on boxes, benches or tables. The stand affords a smooth base for the trap and a place for the flies to alight before entering the trap, and protects the bait from dirt.

Location of fly traps. Fly traps should be located where the flies congregate, that is, near breeding places, such as manure piles or latrines, or in the vicinity of kitchens, mess halls or dumps to which flies are attracted by the odors of food.

As one object of fly control is to protect the food of the troops from contamination by flies, fly traps should be placed outside the kitchens and mess halls, around the garbage stands and near the entrances to the buildings in order to catch the

flies before they have an opportunity to come in contact with and infect the food. Where trapping is employed to reduce the total fly population of a camp or station, traps should also be placed near manure piles and other breeding places so as to capture the newly emerged flies before oviposition occurs.

Fly traps are more effective if an ample number are utilized and if they are placed in groups.

Protection from wind. When the wind tends to prevent flies from entering the trap by rendering it difficult for them to alight, the traps should be placed in the lee of buildings, or such large objects as garbage cans or boxes, which will serve as windshields, but will not darken the trap or interfere with the entrance of flies to the trap.

The fly trap stand may be equipped with a windshield to prevent the flies which are endeavoring to enter the trap from being blown away by the wind (Fig. No. 263). The windshield should extend to a height equal to from one-third to one-half the height of the trap and should be at least 12 inches away from the trap in order not to exclude the light and to permit the flies to enter from all sides of the trap.

Fly baits. A suitable fly bait must have an odor attractive for house flies. It should not constitute a nuisance because of its odor or appearance, and the bait itself, or the raw materials from which it is made, should be cheap and readily obtainable at military posts. The odor should also be of such nature that it disseminates freely through the air in order to draw the flies from a distance. The fly baits commonly employed consist, in general, of either putrefactive or fermented material.

Putrefactive baits. The putrefactive baits consist of spoiled raw meat or fish. Fish heads or canned salmon may be used.

Fermented baits. The fermented baits are those which contain alcohol or in which alcohol is being formed. Usually, they consist of a mixture of cereal, sugar or molasses, yeast and water, which is allowed to ferment before or while being used as a bait. A formula for a cornmeal bait is as follows:

Ingredients—	Cornmeal	8 ounces (by volume)
	Molasses	5 ounces
	Water	16 ounces
	Yeast	½ cake.

Preparation—Mix the water and the molasses and heat to boiling. Pour the molasses and water while boiling, over the cornmeal, stir and allow to cool. Add the yeast and allow to stand exposed to the air for three or four days.

Bran or cornstarch, or bran and cornstarch, may be substituted for the cornmeal if the latter is not available. Syrup made of water and sugar may be substituted for the molasses.

Other fermented baits may be made as follows:

a. Two parts of molasses and one part of vinegar.

b. Molasses which has been allowed to stand exposed to the air for three or four days.

c. Crushed over-ripe bananas in milk.

d. Brown sugar and sour milk.

Comparative efficiency of the different baits. Given comparable conditions relative to location and prevalence of house flies, the putrefactive baits are more efficient than the fermented baits. Assuming that putrefying meat has a value of 100, the comparative value of other fly baits has been found to be as follows:

Putrefying meat	100
Fermenting cornmeal or bran	95
Molasses and vinegar	80

The penetrating, obnoxious odor of a putrefactive bait, either meat or fish, renders it undesirable for use around kitchens, mess halls, latrines, human habitations, or where troops are at work. These baits can, however, be used to an advantage in the vicinity of manure heaps and rubbish dumps where the odors they produce will not create a nuisance.

Under the usual conditions, a fermented bait should be used in the traps placed near kitchens, mess halls, latrines, storerooms, stables, or picket lines, and a putrefactive bait in the traps at the manure piles, rubbish dumps and similar places.

Care of fly traps. Liquid fly baits should be placed in wide, shallow containers so made that flies have easy access to the bait and a relatively wide surface is presented from which the volatile constituents of the bait are readily evaporated. Such containers may consist of an ordinary saucer or a circular piece of tin four or five inches in diameter with a depression in the center so that the liquid spreads to within about one inch of the edge. There should be at least three

inches between the edges of the bait pan and the edges of the trap. Two bait pans should be used in traps which are 18 inches in length, or longer.

The baits should be inspected at least once a day. The solid baits, such as meat or fish, should not be permitted to become dry. The bait pans for liquid baits should be kept filled to the desired level and should be cleaned and refilled whenever a scum forms or sediment accumulates. All baits should be kept free from dirt and dust.

The traps should be emptied whenever a sufficient number of flies accumulate to interfere with the admission of light to the trap chamber or to cover any considerable part of the screening between the trap and bait chambers. Otherwise, flies will not be attracted from the bait chamber by the light in the trap chamber. The flies in the trap chamber may be killed by immersing the trap in water. If a large number of traps are being operated, sulphur fumes may be used to stupefy the flies, after which they are removed from the trap and burned. The sulphur is applied by placing a pan of burning sulphur in the bottom of a barrel and suspending the trap containing the flies in the barrel for a few moments.

It is unnecessary to kill the live flies in the triangular trap (Fig. No. 262) in order to remove the dead insects. The dead flies are shaken out of the trap through the circular opening in the end of the trap and, as the house fly naturally flies upward when disturbed, few if any of the live flies will escape.

If the traps are properly operated, and flies are fairly numerous, it will ordinarily be necessary to empty the traps or remove the dead flies at about weekly intervals.

Fly wires and fly paper. Flies may be captured in considerable numbers on wire or strips of paper coated with sticky preparations known as fly mucilage, fly glue, or tanglefoot. Fly wire or fly paper is employed indoors where it will not catch and retain dust and dirt from the air.

Preparation of fly mucilage. Fly mucilage is made by heating together one part by weight of castor oil and two parts of white rosin. The hot material is stirred while being heated until a sticky, homogeneous mass is obtained. Care should be taken to avoid boiling. A good grade of white rosin should be used, as the crude product renders it difficult to secure a homogeneous mixture and produces an odor that is repellent to house

flies. Variations in atmospheric temperature and in the grade of oil or rosin used may render it necessary to vary the relative proportions of the ingredients.

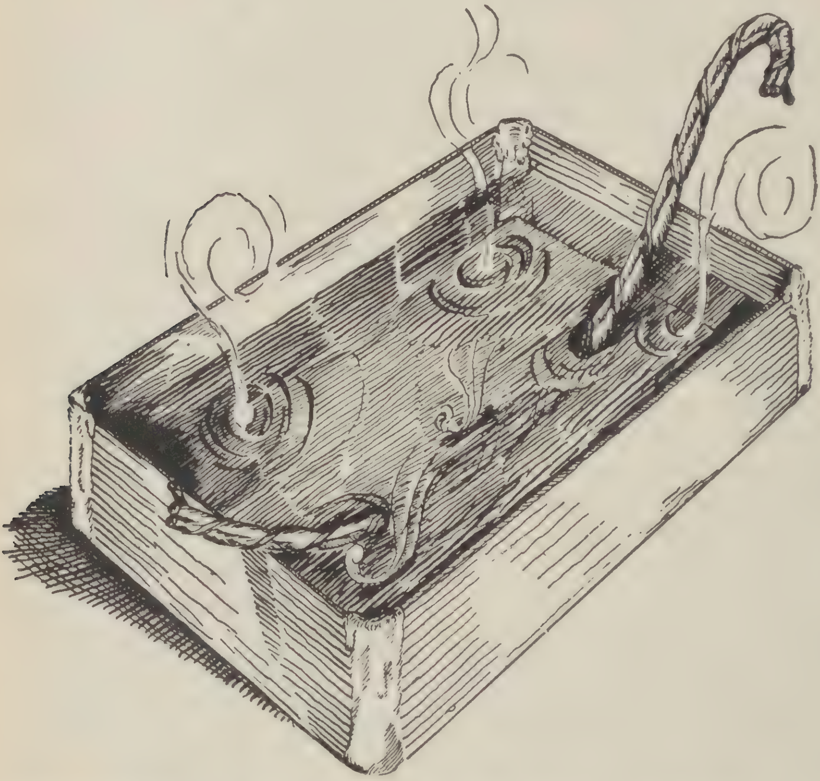


FIG. No. 264. One method of applying fly mucilage to fly wires.

Preparation of fly wires and fly paper. Fly wires consist of pieces of baling wire, or fence or telephone wire, if baling wire is not available. The wires are usually from 18 to 36 inches in length and bent at one end to form a hook or eyelet. The wires may be used singly, but are more easily coated and handled if two or more are twisted together. A coating of fly mucilage is applied by bending the hank of twisted wire slightly and drawing it through the hot mucilage contained in a wide, shallow pan (Fig. No. 264). If a large number of wires are to be coated, they may be dipped vertically into mucilage contained in a galvanized iron can or bucket (Fig. No. 265).

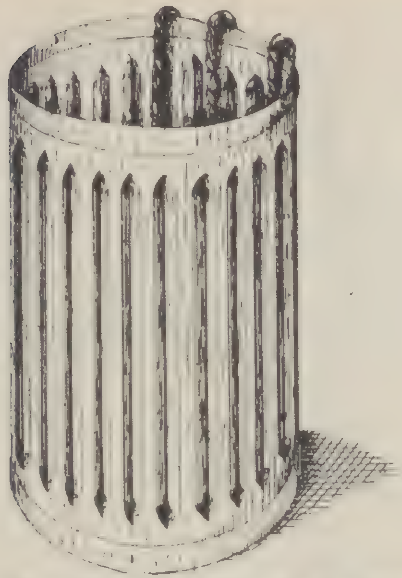


FIG. No. 265. Method of applying fly mucilage to fly wires by dipping the wires into the mucilage contained in a large can.

Fly paper is prepared by applying a thin coat of hot mucilage to each side of a strip of paper. These strips are from 18 to 36 inches in length and from one to two inches in width. Ordinary wrapping paper may be used, but glazed paper is more satisfactory.

Methods of using fly wires and fly paper. In the use of fly wires and paper, advantage is taken of the tendency of the house fly to rest on hanging objects or vertical surfaces by hanging the wires and paper strips from the ceiling or rafters. Fly wires, or fly paper, should not be suspended where flies that come loose will drop on or into food or onto mess tables. When a number of flies have been captured, the wires are wiped with a cloth to remove the flies and the remaining mucilage. The wires are then re-coated and replaced. If paper strips are used, they are taken down and burned. Fly wires and fly papers are useful in the eradication of flies that have gained entrance to buildings and, where indicated, they should be employed in kitchens, mess halls, exchanges, stores and latrines.

Fly poisons. The two substances commonly employed for fly poison are formalin (commercial formaldehyde) and sodium salicylate. These compounds are not dangerous to

man in the dilutions used for fly poisons. Arsenic is an efficient fly poison, but should not be used as such because of the danger of poisoning human beings. When properly employed, fly poison is more efficacious in the eradication of flies than fly mucilage, but it has the disadvantage when used in kitchens and mess halls that the flies are likely to drop into or onto the food.

Formaldehyde poison. The formaldehyde poison consists primarily of from 1.25 to 2.5 per cent of formalin (40 per cent formaldehyde) in water, or about three teaspoonfuls of formalin in a pint of water. As the house fly prefers alkaline substances for food, this poison may be made more attractive for flies by using 50 per cent lime water. Milk and 50 per cent lime water may be used instead of water, or water and lime water. The addition of a small quantity of fermented molasses will increase its attractiveness for flies.

A 2.5 per cent solution of formalin is slightly attractive for flies, but a stronger concentration acts as a repellent. The weaker solutions are less effective as poisons. The efficiency of formalin poison is greater during cool weather than at summer temperatures.

The formalin poison should be freshly made, as the formaldehyde is gradually volatilized when exposed to the air.

Sodium salicylate poison. The sodium salicylate poison consists of a one per cent aqueous solution of sodium salicylate in which a small amount of brown sugar is dissolved. It may be made by dissolving about one or two teaspoonfuls of the powdered sodium salicylate and one teaspoonful of brown sugar in one pint of water. It is more stable than the formaldehyde poison, and sodium salicylate in the solid form is more conveniently handled than formalin. It is only slightly less efficient as a fly poison than the formaldehyde solution.

Methods of using fly poisons. Fly poisons should be exposed in such a way as to be easily reached by flies. Shallow containers made of circular pieces of tin, with a depression in the center, may be used. If deeper containers are used, pieces of bread should be placed in the poison solution to provide a place for the flies to alight. A convenient method is to fill a drinking glass two-thirds full of the solution, place over the top of the tumbler a circular piece of blotting paper the diameter of which is about two or three inches more than the diameter of the glass, and

FIG. No. 266. Method of using fly poison by means of an inverted glass and blotting paper.

cover with an inverted saucer or shallow pan. The whole apparatus is then inverted and a match is inserted under the edge of the glass (Fig. No. 266). The liquid will seep out and maintain the blotting paper in a moist condition until the contents of the glass are exhausted. A little sugar may be sprinkled on the surface of the blotting paper.

Fly sprays. Fly sprays may be used to an advantage for clearing a heavily infested room. They are especially valuable in kitchens and messes for the immediate elimination of flies which might contaminate the food.

Composition of fly sprays. Fly sprays are usually extracts of pyrethrum flowers, containing, in some instances, an essential oil, such as the oil of pennyroyal or citronella. An efficient fly spray can be made by soaking crude pyrethrum powder in kerosene, in proportion of from one-half to one pound of the powder to one gallon of kerosene, for from two to four days. The supernatant liquid is then decanted or siphoned off and is ready for use

as a spray. Its insecticidal power is appreciably increased by the addition of approximately one ounce of the oil of pennyroyal or citronella to one gallon of the extract.

The efficacy of pyrethrum as an insecticide depends upon the pyrethrin content of the particular lot of pyrethrum used. Extracts of pyrethrum are available on the market in which the pyrethrins extracted from 20 pounds or more of the standardized pyrethrum flowers are contained in one gallon of the extract.

A fly spray which is approximately equal in toxicity to the kerosene spray described above can be made by diluting the concentrated extract with twenty volumes of kerosene. A more potent spray may be made by using a proportionately greater quantity of the extract.

A satisfactory fly spray can be made by extracting one pound of the crude pyrethrum powder in one quart of ethyl alcohol for 24 hours and diluting the resultant liquid extract with four parts of water. One ounce of the oil of pennyroyal or citronella should be added to each gallon of the diluted extract.

Another effective spray is made by extracting one pound of pyrethrum with one quart of chloroform for several hours. The extract is then filtered and the filtrate diluted with sufficient kerosene to make one gallon.

Kerosene containing five per cent of citronella oil is also an effective fly spray.

Derris root powder may be used in lieu of pyrethrum and is extracted with kerosene in the same manner as pyrethrum. Rotenone is the active principle of derris root. Frequently, flies and other insects are only paralyzed or stunned by pyrethrum and subsequently recover, while derris kills them. However, pyrethrum acts much more rapidly than derris and is more effective in producing immediate results. The derris extract is odorless and colorless and does not leave a stain. Pyrethrum extract has a characteristic odor and a yellow color. When a considerable quantity of pyrethrum extract is used it may stain fabrics, plaster or paper.

Application of fly spray. The spray is applied by means of a small hand sprayer. It is most effective when applied to groups or clusters of flies that are resting on ceilings or walls. Care should be taken not to wet the surface on which the flies are resting. Where flies are numerous in mess halls and kitchens, the

windows and doors should be closed and the entire room sprayed at routine intervals, usually after each meal.

Dusting powder. Pyrethrum powder has a paralyzing effect on insects and may be used as a poison to eradicate house flies from a room or building. The doors and windows of the room to be treated are closed and the larger incidental openings covered with pasted paper. The powder is sprayed into the room as a dust cloud with a large dust blower until the air is heavily charged. After about one hour the room is opened and most of the flies will be found lying on the floor. As the flies are only stunned, they should be swept up and burned at once.

Fumigation. Fumigation may be used to destroy at one time all the flies in a room or building. Ordinarily, the results attained do not justify its use.

Fumigants and methods of using. Sulphur and pyrethrum are the two most effective and most commonly used fumigants for the destruction of the house fly. The room or building to be fumigated should be sealed by closing tightly all the doors and windows and by pasting strips of paper over all cracks and crevices opening to the outside.

Both the sulphur and the pyrethrum are converted into gaseous forms by burning. Usually, the fumigator consists of a pan or other metal container to hold the burning chemical. The container should be placed in a larger vessel containing water to safeguard against fire. The sulphur or pyrethrum is placed in layers in the pan, moistened with alcohol, and ignited. Both the sulphur and the pyrethrum are applied at the rate of two pounds for each 1000 cubic feet of air space. The sulphur dioxide should be allowed to act for about one hour and the pyrethrum for four hours. If pyrethrum is used, the paralyzed insects must be swept up and destroyed as soon as the fumigation is completed.

Swatting. Fly swatting in kitchens and mess halls is a valuable control measure for the removal of a few flies. If large numbers are present, spraying is more effective than swatting. Swatting is a most valuable procedure when employed just before the food is placed on the table, but it cannot be relied upon as a sole measure to protect the food from flies.

Screening. While screening has no effect in reducing the number of flies, it is a most important measure in prevent-

ing existing flies from gaining access to food. Consequently, all buildings containing kitchens, mess halls, exchanges, or other installations in the operation of which food is necessarily exposed, should be screened against flies.

Kinds of screening. If house flies only are to be excluded, the screening should have a mesh of 14 wires to the inch. If the screening must also exclude mosquitoes, it should have a mesh of 16 wires to the inch if Anopheles are present, and 18 to the inch if *Aedes egypti* are to be excluded.

Black enameled steel or galvanized iron wire may be used, except in the coastal areas in the temperate zone and in the tropics where the hard drawn copper wire containing not less than 99 per cent copper should be employed (page 943).

Installation and maintenance of screens. The same methods and precautions should be employed in the installation and maintenance of screens to exclude the house fly as in the case of screens employed against mosquitoes (page 944).

All food containers in which the food is exposed, such as bread cabinets, should be screened to protect the food from flies. All food being transported in the open, as in the case of bread or meat being taken to the kitchens or mess halls, should be so wrapped or packed as to deny access to flies.

CHAPTER XIX.

RAT CONTROL

The rat is a factor in the spread of disease mainly because it serves as a host for the rat flea and as an animal reservoir of plague and endemic typhus fever. It may be concerned in the transmission of other diseases by mechanically transferring the causative organisms from waste materials, such as human excreta, to the food of man. Rats may be carriers of intestinal parasites, particularly tapeworms. They are also frequently infested with *Trichinella spiralis* and are a factor in transmitting the infestation among hogs.

The rat is also a carrier of the *Leptospira icterohaemorrhagiae,* the causative agent of infectious jaundice, and may transmit the disease to man by contaminating the food with excreta containing the leptospira. The etiological agent of rat-bite fever (*Spirillum minus*) is transmitted to man by the bite of a rat.

CLASSIFICATION

The genus *Rattus,* family *Muridae,* includes three species that are of sanitary importance. These are the brown rat, or *Rattus norvegicus,* the black rat, or *Rattus rattus,* and the roof rat, or *Rattus alexandrinus,* which is also known as the Egyptian rat.

The brown rat is the largest of the three species. It is brownish in color, the tail is shorter than the body and the ears are pointed and relatively small. The black rat is bluish black in color, the tail is longer than the body and the ears are large and rounded. It is about two-thirds the size of the brown rat.

The roof rat resembles the black rat, except that the fur on the sides of the body is gray and that on the abdomen is white or yellowish white.

HABITS AND CHARACTERISTICS OF RATS

Rats of all species are nocturnal animals. In daylight, the rat moves slowly and with some degree of uncertainty, unless it can run along a wall with which its vibrissae (feelers) make contact. The rat prefers to travel through narrow passages or on runways along a wall, a habit which is an important factor in the success of trapping and poisoning procedures.

Rats tend to migrate in accordance with variations in the abundance and accessibility of their food supply and the availability of shelter. These migrations may be seasonal, as for example, when they migrate from buildings into the fields in the spring of the year and return in the autumn. In other instances, they will permanently vacate a building because of failure of the food supply. A greater or less proportion of the rat population of a given area or building may migrate at one time or individuals may wander from place to place in search of food or shelter, or to escape danger.

All species of rats, but more especially the brown rat, travel over the world in ships, or on trains or other agencies by which edible goods are transported. The tendency of rats to travel along trade routes is an important factor in the spread of plague from country to country.

The brown rat is more ferocious than either of the other two species. It will attack either black rats or roof rats and drive them from the vicinity or into the upper part of a building where it cannot easily follow. As a result of this characteristic, together with its greater fecundity, the brown rat is widespread over the world, while in the United States black rats are seldom found far away from seaports.

The principal harboring places for rats at military stations or camps are in or under stables, dumps, warehouses, storerooms, or empty buildings, or in burrows under walks or in out of the way places, where they are the least likely to be disturbed and from which they can make nightly excursions in search of food. They are less apt to nest in such buildings as quarters or barracks.

The rat is capable of great cleverness in preventing its presence from becoming known, except by the depredations it commits which may be attributed to other causes. Consequently, a station may support a large rat population even though only a few of the animals are seen.

The brown rat. The brown rat (*sewer rat*) is the common rat of the temperate zone. It is a burrowing animal and prefers to live in holes or similar excavations, rather than in buildings above ground. The burrows of the brown rat are usually not more than 12 inches and seldom more than 18 inches deep. It can and will burrow through hard packed clay, or the lime mortar and sand in wide spaces between the stones or bricks in a wall. It may also gnaw holes in lead pipes or slate. The brown rat is clumsy, a poor jumper, and does not climb as readily as the black or roof rat. For this reason it commonly feeds on or near the ground and harbors in the ground or in those parts of a building which are readily accessible from the ground.

The brown rat produces from three to five litters each year. The average litter consists of from 8 to 10 young, and of this number about half survive to maturity. The number of litters and the number of young per litter is increased above the average when the food supply is ample and the climatic conditions are suitable.

The brown rat is a scavenger and will, in the absence of more desirable food, consume decomposing material.

The black rat. The black rat does not ordinarily live in burrows but prefers to nest in hollow spaces in walls, in rubbish in boxes, barrels or other containers, in the attics or upper stories of buildings, or in trees. It can easily climb pipes, ropes, wires or wooden uprights and thus reach the upper part of buildings and escape from the localities frequented by the brown rat.

The black rat produces an average of six young per litter and is therefore less prolific than the brown rat. It differs also from the brown rat in that it shows a greater preference for clean food, such as grain.

The roof rat. The roof, or Egyptian, rat is the cane field rat of the tropics. It is at times found in buildings where it exhibits the same habits and characteristics as the black rat.

CONTROL PROCEDURES

Rat control measures are either suppressive or destructive in nature. Suppressive measures are designed to prevent rats from reaching a food supply and to deny them access to spaces in which they can nest and breed. Destructive measures are designed to destroy the individual rat by poison, trapping, fumigation or natural enemies. The most effective measures for the continued control of rats within a given area are those which prevent the rat from reaching a food supply and which deny it shelter and concealment.

Procedures designed to destroy rats by poisoning, trapping, fumigation or by natural enemies, usually fail unless they are skilfully and continuously prosecuted. Usually, no one measure alone will serve to reduce materially the rat population of a given locality, and, consequently, several different procedures must be simultaneously or successively employed. Thus, for example, at a station or camp, an anti-rat campaign may consist of rat proofing all or a part of the buildings, and storing food and disposing of food wastes so that they are not accessible to rats, followed by poisoning which is in turn succeeded by trapping the survivors and filling in the burrows. Such a campaign, if properly organized and persistently conducted, will reduce the number of rats to a minimum, or exterminate all those present at the time of the campaign.

Sporadic or poorly planned and unorganized efforts are of little permanent value in reducing the rat population, as those destroyed are soon replaced by young rats or by those that wander in from other places.

RAT PROOFING

The purpose of rat proofing is to render it difficult for a rat to enter a building and thus reach a food supply or to gain access to spaces which will provide shelter and concealment from its natural enemies. Buildings are rat proofed by elevation, or by the use of concrete floors and walls of concrete or of brick or stone laid in cement mortar, with the occlusion of all openings with metal flashing or metal grating or screening.

Methods of rat proofing. The methods best suited for rat proofing a particular building depend somewhat on the type of building concerned. Rats can be excluded from buildings in which food supplies are stored, such as warehouses, mess buildings, post exchanges, or commissaries, only by measures which will prevent all possible access to the interior. Other buildings, such as barracks, quarters or offices can be rat proofed by less complete measures.

Rats enter a building by burrowing under the walls and upward through the floors, by gnawing through wooden walls close to the ground, and by crawling through incidental openings such as ventilators, unused drains, windows, or air or light shafts. Black rats may climb piping or wires to reach openings into the buildings. Rats may seek protection and harborage in double walls or ceilings or in any enclosed dead space. All these factors should be considered, and the neglect of any one feature may nullify all other measures taken to rat proof a building.

Ordinarily, concrete or brick buildings may be made rat proof by the closure or protection of incidental openings which would permit the entrance of rats. Wooden buildings are rat proofed by the use of concrete floors, concrete area or foundation walls, or by elevation.

Concrete floors and concrete area walls. The concrete floor installed for rat proofing purposes should be not less than three inches thick and should have a top dressing of cement at least one inch thick. The margins of the floor should be sealed into an area wall of concrete or of brick or stone laid in cement mortar (Fig. No. 267).

An area wall is a wall which extends completely around the building. It should be at least four inches thick. It should extend at least two feet below the surface of the ground and not less than one foot above the upper surface of the floor, except at doorways where it extends upward only to the level of the floor (Fig. No. 268).

The sill supporting the studding should, preferably, rest directly on top of the area wall. Where this cannot be done the walls of the building may rest on the floor immediately inside of the area walls. In any event, there should always be a tight union between the concrete floor and the area walls.

Cellar or basement walls. The walls of basements and cellars should be at least six inches thick and made of concrete, or of brick or stone laid in cement mortar. They should be sealed into the floor of the buildings so that there is no intervening space. The floor of the basement or cellar should be made of concrete and should be at least three inches thick.

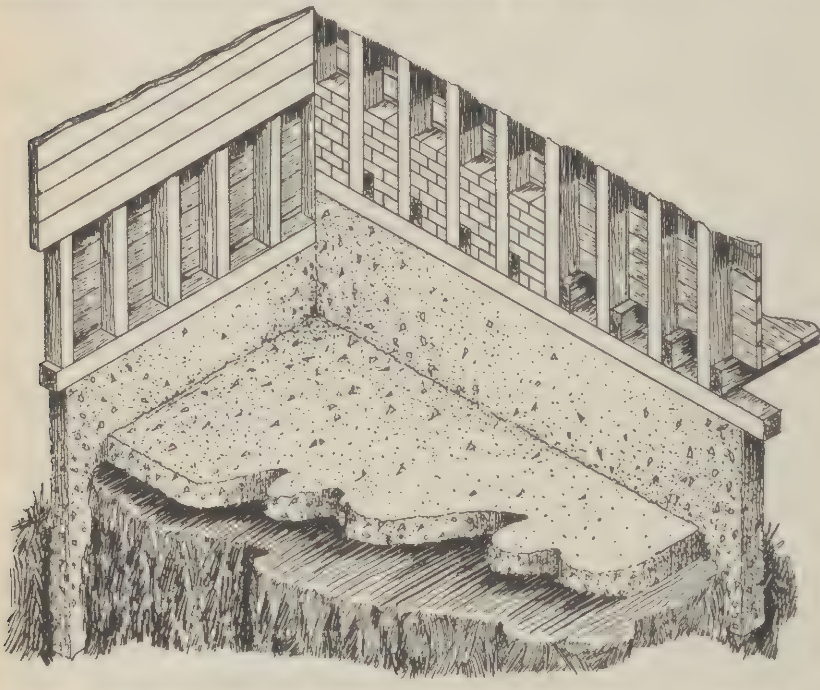


FIG. No. 267. (Schematic). Method of rat proofing building with area wall and concrete floor. Openings between studding closed with brick.

Sustaining or foundation walls. Buildings which are not used to store food supplies may be rat proofed by the installation of a sustaining or foundation wall of concrete extending entirely around the ground area of the building. A sustaining wall should be at least four inches thick. It should extend down into the ground at least two feet and join the floor of the building in such a manner as to leave no intervening spaces. This method is most suitable for rat proofing inhabited buildings where there is no danger that rats will be permitted to gnaw through the floor from above to reach harborages beneath (Fig. No. 269).

Elevation of buildings. Small buildings may be rat proofed by elevation to a height of at least eighteen inches on piers made of concrete, or of stone or brick laid in cement mortar. Where existing buildings are supported on wooden posts or piers, the posts or piers should be covered with metal, such as tin or

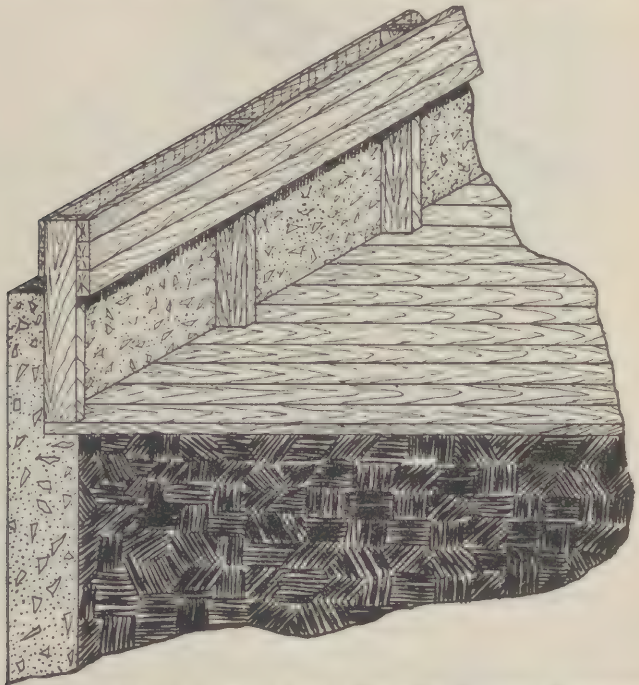


FIG. No. 268. (Schematic). Method of rat proofing building by concrete area wall extending one foot above and two feet below the floor.

sheet iron. The space below the building should be open on three sides and kept free of rubbish and debris which might provide harborages for rats. Buildings rat proofed by elevation should be separated from other buildings on three sides by a space at least ten feet in width (Fig. No. 270).

Stables. Stables may be rat proofed by installing a wall around the ground area of the building. This wall should be at least six inches thick and should extend from a depth of at least two feet below the surface of the ground to a height of not less than one foot above the floor level.

Stable floors should be of concrete and at least three inches thick with a top dressing of cement not less than one-

half inch thick. The superstructure should be so constructed that there are no double floors, ceilings or walls containing open spaces.

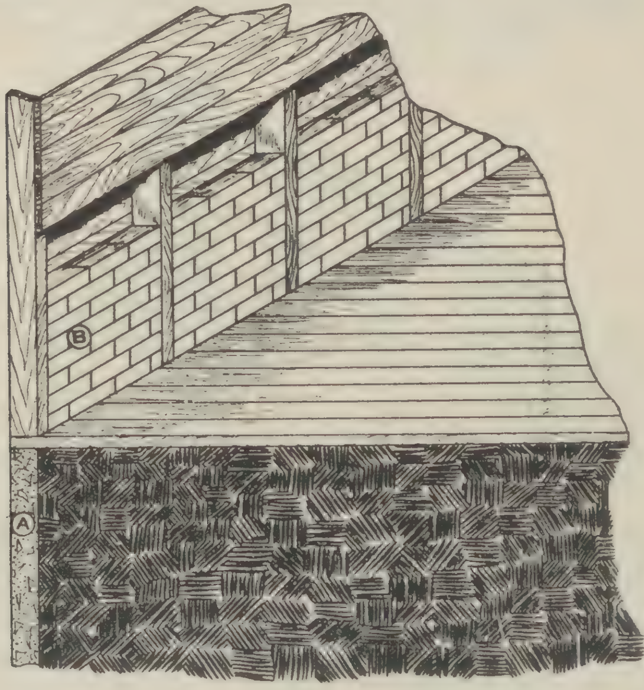


FIG. No. 269. (Schematic). Method of rat proofing by: A—Concrete foundation wall; B—Closure of openings between studding with brick.

Objections to concrete standings in stalls may be met by constructing stall floors of planking laid on top of the concrete floor. The plank floor should be so laid that there will be not more than one-half inch of space between the planks and the concrete floor below. Wooden blocks set in the concrete may also be used instead of planks.

All feed bins should be made of concrete and have close fitting doors. If made of wood, they should be lined with metal.

Closure of incidental openings and elimination of rat harborages. The space between the ceiling of one room and the floor of the room above may afford shelter and concealment for rats. If a ceiling is necessary, this space can be rat proofed

by placing a flashing of galvanized metal completely around the margin of the floor above. The flashing should extend six inches up on the wall and six inches out on the floor.

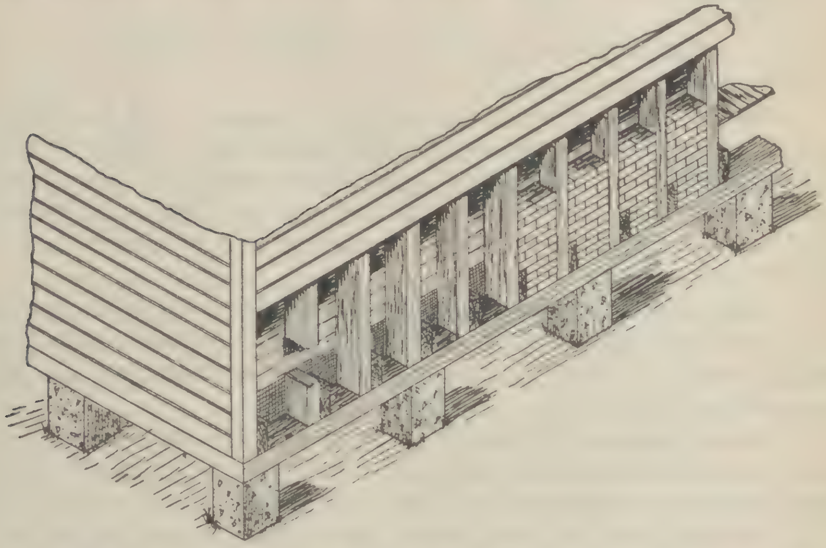


FIG. No. 270. (Schematic). Rat proofing by elevation, with closure of openings between studding with brick.

In the case of buildings which are rat proofed with a sustaining wall reaching upward only to the floor, double walls immediately above the floor may be rat proofed by removing the weatherboarding and placing brick laid in cement mortar between the studding to a height of about one foot above the floor (Fig. No. 269).

All openings or crevices, other than doors, windows and ventilators, should be closed with concrete, or brick or stone laid in cement mortar. If they are not closed, they should be screened with a metal grating in which the openings are not more than one-half inch wide, or with wire screen of not less than 12 gauge wire nor more than one-half inch mesh. All ventilators which are near the ground and all basement windows should be screened in a like manner.

The bottom of doors which open at the ground level should be covered on the outside with galvanized metal to a height of at least six inches.

All drains should be so laid that no spaces are created through which rats could gain admittance to the building.

Board walks or plank roads should be replaced by concrete, metal or cinders.

PREVENTING ACCESS OF RATS TO FOOD

It is difficult, if not impossible, to eradicate all rats from a locality if they have access to a food supply. While it may be impracticable to prevent rats from obtaining any food, measures which will produce a shortage of food will reduce the breeding rate and render poisoning and trapping procedures more effective.

The most efficient method of preventing rats from reaching food supplies is to store the food in rat proof buildings and dispose of edible wastes in such manner that they are not accessible to rats.

In the absence of rat proof buildings, the food should be stored so that it is inaccessible to rats that gain entrance to or are harbored within the building. This may be accomplished by elevating all food materials two feet or more above the floor on stands or racks. The stands or racks should be at least two feet from any wall. In other instances, rat proof rooms may be constructed, or, where small quantities of supplies are to be stored, metal containers may be employed.

All garbage should be placed in garbage cans having tight lids and spillage should be avoided. Care should be taken to keep garbage cans covered. All garbage should be promptly and completely disposed of.

No material which would serve as food for rats should be placed on dumps, or if disposed of by dumping, it should be immediately burned.

POISONING

Poisoning is an effective rat control measure where there are many rats on the premises or if a large colony is to be attacked.

Poisoning will not destroy all the rats in a locality, as the survivors soon become suspicious and will not take the baits. This disadvantage may be overcome in part, and greater suc-

cess attained, by placing a large number of baits at one time and by frequent changes in the kind of bait or the kind of poison used. Eventually, a point will be reached where only new arrivals that wander into the locality and young rats will be killed by the poison, as the older members of the permanent population become suspicious and refuse to touch the poisoned baits. The latter must then be killed or driven away by other means, such as trapping.

Poisons. The compounds most commonly used as rat poison are red squill, barium carbonate, arsenic, phosphorus, strychnine and thallium.

Red squill. Red squill is the most desirable rat poison for use at army stations and installations. It is extremely toxic for rodents, but because of its emetic action it is not poisonous for other animals or for man. Rats cannot vomit and cannot eliminate the poison. A large number of baits containing red squill may be distributed without danger to children, dogs or cats. Despite its somewhat acrid taste, red squill is readily eaten by rats. Also, as its action is delayed for several hours, hungry rats are not frightened away from the poisoned baits by the presence of sick animals. As red squill kills slowly, the poisoned rat tends to return to its burrow and does not die between the walls or under the floors of the building. Occasionally, if the rat harborages are near or in a building, an odor will be present and may be obnoxious for a few days.

Different lots of red squill vary considerably in toxicity, and care should be taken to obtain a satisfactory product. The flue or oven dried squill, and not the sun dried product, should be used.

Barium carbonate. Barium carbonate is a heavy, odorless, tasteless powder. It is poisonous for rats in small quantities and is also lethal in larger doses for dogs, cats and larger animals. A dose of about 2 grains will kill a rat, while 15 grains are required to kill a chicken and 100 grains to kill a dog. It is relatively non-poisonous for man, except when consumed in large doses.

Barium carbonate produces an intense thirst and tends to cause the poisoned rats to leave the buildings in which they harbor in search of water. Consequently, many of the rats poisoned with barium carbonate will die in open places from which the carcasses can be readily removed.

Arsenic. Powdered arsenious oxide, being tasteless and odorless, is the most effective rat poison, especially if the finely pulverized, gritless form is employed. However, as it is highly toxic to other animals and to man, the fact that it is tasteless and odorless renders its use as a rat poison extremely dangerous.

Phosphorus. Phosphorus is the active ingredient of many of the commercial rat poisons. The use of phosphorus as a rat poison is attended by considerable danger of accidental poisoning of man or domestic animals, although its luminous property and its taste and odor, which are not repellent to rats, tend to prevent the ingestion of the baits by other animals. It is, however, too dangerous for ordinary use as a rat poison, unless extraordinary precautions are taken to prevent accidents.

Strychnine. Strychnine is highly poisonous to rats but it has the disadvantage that its bitter taste must be counteracted, and its rapid action tends to cause the rats to die within the walls and in inaccessible parts of a building. Care must be exercised to prevent its ingestion by other animals.

Thallium. Thallium sulphate is widely used as a rat poison. The action of thallium sulphate is similar to that of arsenic and, as it is also tasteless and odorless, it has practically the same advantages and disadvantages as arsenic.

Baits. The baits used to carry the poison consist of food materials of which rats are particularly fond. Included in this category are ground meats, fried bacon, fish, liver, grated or toasted cheese, sweet corn, sweet potatoes, apples, tomatoes, and cereals, especially rolled oats and corn meal.

The bait selected should, in each instance, be a food material similar to that which is, or has been, otherwise readily accessible to the rats. At times, rats that have been accustomed to a diet of grain will not take a fish or meat bait, or those that have had access to meat products will not eat a cereal bait. Ground meat and finely ground fish are usually the best bait materials. A good bait consists of corn meal mixed with about ten per cent of ground cod fish. The cod fish ingredient may be replaced by from five to ten per cent of grated cheese.

Preparation. The consistency of bait should be such that it can be cut or shaped into small cubes, balls or small flat cakes. The cubes or balls of bait are usually about one-half inch in diameter, and the flat cakes about one-quarter inch thick and

one inch in diameter. If soft or powdered materials are used, usually about one-half of a teaspoonful is sufficient for one bait. Rats frequently prefer greasy food, and tallow or butter may be used to an advantage to produce cohesion between the particles of such finely divided bait materials as cereals, ground meats, fish or cheese. A soft, well moistened bait is more attractive to rats than one that is hard and dry.

Rats will, at times, refuse to eat baits that have been handled by man, probably because of the odor derived from the hands. Care should therefore be taken to avoid unnecessarily touching the bait with the hands during its preparation. An instrument, such as a knife, should be used whenever practicable to mix the bait materials.

Red squill baits are usually prepared from fish, meat or cereals to which the red squill is added in proportion of one part of the poison to 16 parts of the bait. One ounce of powdered red squill is mixed with a small amount of water to form a thin homogeneous paste. The paste is added to and thoroughly mixed with one pound of finely ground meat or fish. Fresh fish is a good bait, but canned salmon is nearly as effective as fresh fish. If a cereal, such as oatmeal, cornmeal, graham flour, or bran, is used, one ounce of powdered red squill is added to and intimately mixed with one pound of the cereal. One pint of fresh milk or water is added and the mass stirred to a mush-like consistency.

Barium carbonate should be used in proportions of one part by weight of the poison to two parts of the bait. Arsenic is usually employed in the proportion of one part of the poison to five parts by weight of the bait.

Distribution of the poisoned baits. Each bait should be placed in a small paper container, or torpedo, made by wrapping the bait in a piece of paper, the ends of which are twisted together. This method enables the rat to carry the bait to a secluded place for consumption and frequently rats will eat a bait thus prepared when they will not touch those that are openly displayed.

The baits should be laid in places that are easily accessible to and frequented by rats. Generally, the best results are obtained when the baits are placed along rat runways leading from the rat harborages. These runways usually lie alongside of walls or other similar objects. Good results may

also be obtained when the baits are placed in rat burrows or near protected food supplies in storerooms, warehouses, or stables.

The baits may be placed singly or in groups. Frequently, several kinds of bait may be used in one place, as, for example, a ground meat bait, together with a cereal bait. When several kinds of bait are exposed together, the kind taken by the rats will indicate the type of bait preferred by the particular rat population concerned. For instance, if the ground meat baits disappear and the cereal baits remain, then thereafter most or all of the baits distributed should consist of ground meat. Within limits, poisoning will be more effective when a large number of baits are used. Single baits, or groups of baits, should be placed not more than 10 to 20 feet apart along runways or in areas frequented by rats in search of food.

Poison caches may be employed where there are only a small number of rats present or where poisoning is used only to destroy rats that are migrating onto the premises. A poison cache consists of a collection of several baits in a protected runway by which the rats reach a food supply or enter a building. Poison is kept in the cache at all times, but the best results are attained if the cache is inspected daily and the uneaten baits replaced with a fresh supply.

Care should be taken to touch the baits as little as possible during their distribution. Ordinarily, a convenient method is to distribute the baits by means of a spoon or with pliers which have been flamed to remove the human odor.

The baits should be prepared and distributed in the late afternoon or evening so that they will be fresh when the rats begin their search for food. The uneaten baits should be removed the next morning to prevent souring or spoilage which would render the bait material distasteful to rats.

If the poison used is red squill (*supra*), it is seldom that the dead rats are seen, but the number of baits that disappear may be taken as a rough measure of the number of rats destroyed. Where the baits are not accessible to other animals, if one bait is taken it may be considered that one rat has been poisoned. Unless the rats are very numerous, and hungry, only a small proportion of the baits distributed will be taken. Under the usual conditions, results may be regarded as satisfactory if two or three per cent of the baits are taken each time they are distributed.

Occasionally, as many as ten per cent of the baits may disappear, and if the rats are very numerous as high as thirty per cent or more of the baits may be eaten the first time, or the first few times, the baits are placed.

Pre-baiting. In order to accustom rats to eating the kind of food materials which will be used to carry the poison, unpoisoned baits which are exactly like those that are to be employed later, except that they contain no poison, may be distributed for several days prior to placing the poisoned baits. The uneaten baits should be collected daily and replaced with fresh material. When the unpoisoned baits are eaten freely by the rats, all those that remain uneaten should be collected and a comparatively large number of poisoned baits distributed. Frequently, this procedure will result in the destruction of a large proportion of the rat population.

TRAPPING

Trapping is an effective rat control measure, but requires greater skill and more labor than poisoning. A readily accessible food supply decreases the efficiency of trapping as a rat control measure.

Rats soon become suspicious of traps, particularly if the traps are unskilfully set, and will then consistently avoid them. Where many rats are present, a comparatively large number of traps should be set at the beginning of the campaign in order to destroy as many rats as possible before they learn to avoid the traps.

Trapping is a very practicable and efficient procedure for the control of rats in large warehouses or storerooms, if it is persistently and systematically carried out. It also has the advantage that it can be constantly employed to destroy new arrivals where the continued exposure of poison would be undesirable.

Types of traps. The snap trap (guillotine or spring trap) is the most effective and generally useful trap for routine use (Fig. No. 272). The type of snap trap selected should be strong and durable and preferably made of steel.

Cage traps similar to that shown in Fig. No. 271 may be employed. They have the disadvantage that the rats soon become suspicious and will not enter them.

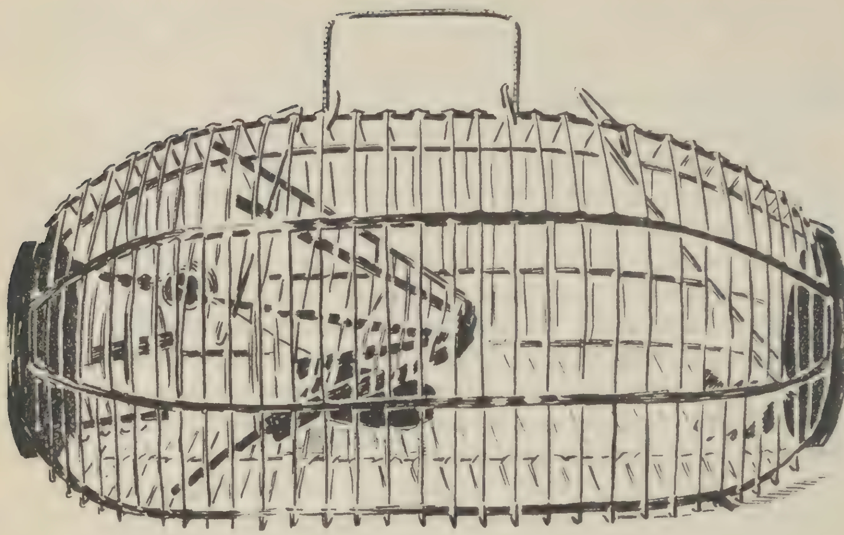


FIG. No. 271. Cage rat trap.

Trap baits. Solid or semi-solid baits which can be fastened to the trigger of the trap are the most effective. These baits include such articles as fried bacon, fish, cheese, liver, fresh bread or doughnuts, cantaloupes or tomatoes. While the kind of bait should be similar to the food which is otherwise available to the rats, usually fried bacon, cheese or doughnuts will prove attractive. A mixture of butter and rolled oats or cornmeal and ground cod fish smeared on the trigger of the trap may be successful at times.

Where a number of traps are set, different baits may be used at the same time. If the trapping is continuous, the kind of bait used should be changed from time to time.

Trap setting. If a solid or semi-solid bait is used, it should be large and fastened to the trigger of the spring trap either by tying with a string or strong thread or by means of a hook which is a part of the trigger. If cereals or soft baits are used, they may be smeared over the surface of the trigger or scattered over the base of the trap below the trigger.

The traps must be placed in locations normally frequented by rats. Usually, they are set in runways along walls, behind or between objects, or in other places that afford the rats complete or partial concealment.

Where the trap is set on a runway alongside of a wall, it should be placed with the trigger end of the trap next to the wall. At times the traps may be set between a wall and a box, or between two other objects, so that the rat in passing along the runway will step on the trigger even if the bait is not disturbed (Fig. No. 272).

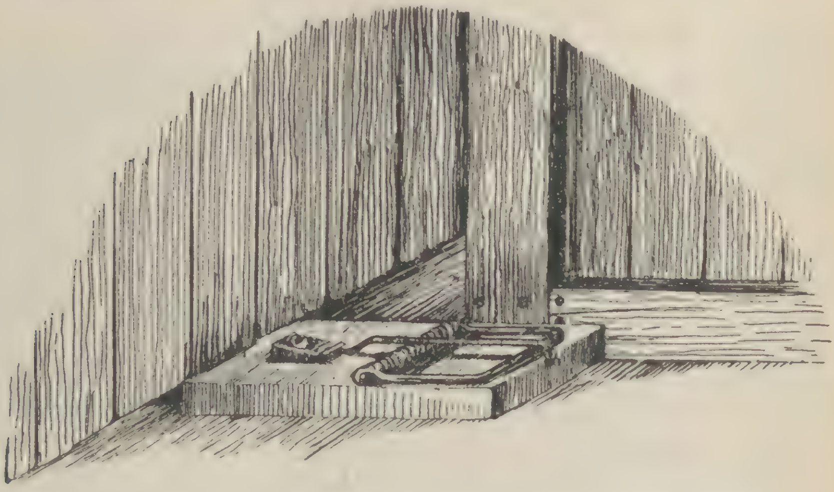


FIG. No. 272. Method of setting rat trap across a narrow runway.

When the rats become wary and difficult to trap, the number caught may be increased by partially or completely covering the trap. The trap may be placed in an excavation in the ground, or between boards, so that the surface of the trigger is level with the earth or floor. Such a trap may be left exposed or covered with paper which is in turn hidden by earth. A trap may also be completely hidden in a shallow box or pan by covering with grain, rolled oats, cornmeal or other cereal. The box or pan may be pre-baited without traps until the rats become accustomed to feeding therefrom, after which the traps are placed.

Occasionally, suspicious rats may be caught by placing traps which are baited but not set and allowing them to take the baits several times. The traps are then set and if skilfully done, this procedure will usually be successful.

Precautions in handling and setting traps. The trigger should be so adjusted that the slightest touch will spring the trap. The trap should not be handled unnecessarily with the hands, and

tongs or pliers should be used whenever practicable. All traps should be scalded or flamed at intervals to remove the odor derived from the hands. Traps may be deodorized by dipping in hot melted paraffin. The coating of paraffin decreases the amount of odor that will cling to the trap after it has been handled.

FUMIGATION

Rats may be killed in buildings, in ships, or in their burrows by means of gas. The gases commonly employed for this purpose are hydrocyanic acid gas, sulphur dioxide, carbon disulphide or carbon monoxide.

Fumigation of buildings. In order to destroy rats in buildings by fumigation, the gas employed must be readily diffusible and must be lethal to rats. It should be of such nature that it can be easily and rapidly generated, and will produce a minimum of damage to the materials stored in the building. The building to be fumigated should be so constructed that it can be made sufficiently air tight to maintain a lethal concentration of the gas for the required period of exposure.

The gases commonly used for the destruction of rats in buildings are hydrocyanic acid gas and sulphur dioxide.

Hydrocyanic acid gas. Hydrocyanic acid gas is extremely toxic for all animal life and is the most effective and the cheapest fumigant for the destruction of rats. It diffuses rapidly and penetrates into all parts of the building. Hydrocyanic acid gas does not injure textiles, foodstuffs or painted surfaces. It may cause a slight tarnish on highly polished metal surfaces.

As small quantities of hydrocyanic acid gas are rapidly fatal to man, it should be used as a fumigant to kill rats only when the precautions necessary to protect the workers can be properly enforced.

Where hydrocyanic acid gas is used as a fumigant, care must be taken that the room or building is properly prepared by sealing all cracks and incidental openings, and all windows and doors, except the door through which the men applying the fumigant are to leave the room or building. The latter is closed, and sealed if necessary, immediately after the fumi-

gant is released and all persons are outside. Regardless of the form of hydrocyanic acid used, at least two ounces should be applied per 1000 cubic feet of space to be fumigated, and the time of exposure should be at least two hours for empty spaces and four hours where the room or building contains materials of any kind.

Hydrocyanic acid may be employed as a fumigant in the form of Zyklon (Zyklon-B), HCN discoids, calcium cyanide, liquid hydrocyanic acid, or the liquid acid modified by the addition of a compound which serves as a "warning gas". Zyklon or HCN discoids offer by far the most practicable method of using hydrocyanic acid as a fumigant to destroy rats in buildings. Liquid hydrocyanic acid is more difficult to apply than Zyklon or the HCN discoids and is more dangerous.

Zyklon. Zyklon is an earthy substance impregnated with liquid hydrocyanic acid, which when exposed to the air releases hydrocyanic acid gas. Zyklon gives off all of its contained hydrocyanic acid and the material remaining is nonpoisonous. Zyklon is available in cans containing 15 grams, 120 grams, 480 grams and 1200 grams of hydrocyanic acid, and five per cent chloropicrin which acts as a warning gas. Zyklon is applied by punching holes in the can and sprinkling the desired amounts on the floor of the room or building to be fumigated. It should be used in quantities of 60 grams per 1000 cubic feet of space.

HCN discoids. HCN discoids are disks of wood pulp which have absorbed a definite amount of hydrocyanic acid. One size is $3\frac{3}{8}$ inches and the other is $5\frac{1}{8}$ inches in diameter. The former contains one-fourth ounce and the latter one-half ounce of hydrocyanic acid, and, in addition, 5 per cent chloropicrin. The HCN discoids are available in sealed cans, each containing a certain number of discoids and a specified net quantity of hydrocyanic acid.

When exposed to the air, HCN discoids give off hydrocyanic acid gas in quantities depending on the size of the discoids, that is, either one-fourth or one-half ounce per discoid (*supra*). After exposure for from two to four hours, the discoids contain little or no hydrocyanic acid and are nonpoisonous. HCN discoids are distributed on the floor of the room or building in such numbers as will release hydrocyanic acid gas at the rate of two ounces per 1000 cubic feet of space.

Liquid hydrocyanic acid. The boiling point of high grade hydrocyanic acid is 74°F. It is very volatile in warm, dry air and diffuses rapidly when released as a gas. For fumigation purposes, hydrocyanic acid is marketed as a liquid in steel cylinders. When released from the cylinders under pressure it is sprayed into the air and volatilizes at once. The necessary pressure within the cylinder is provided by an air pump operated by a motor, and the acid is carried by a rubber hose from the cylinder to the space to be fumigated. The cylinder may be placed on a scale and the amount of acid released determined by difference in weight.

The acid is usually shipped in cylinders weighing about 75 pounds, and may be transferred to smaller cylinders for use. In time, liquid hydrocyanic acid deteriorates and becomes explosive, and the cylinders must be returned to the manufacturer within three months.

The warning gases used with hydrocyanic acid produce lacrimation and consist of cyanogen chloride or chloropicrin. The liquid hydrocyanic acid produced by manufacturing firms for fumigation contains 20 per cent cyanogen chloride, or 5 per cent chloropicrin.

Hydrocyanic acid gas may be generated within the space to be fumigated by mixing sodium cyanide with an acid in crocks or other containers. A mixture of cyanogen chloride and hydrocyanic acid gas may be generated by the addition of sodium chlorate to a mixture of sodium cyanide and hydrochloric acid. The ingredients and the amounts used to generate sufficient gas to fumigate 1000 cubic feet are as follows:

*Hydrochloric acid	17 ounces
Water	17 ounces
Sodium chlorate	3 ounces
Talc	2 ounces
Sodium cyanide	4 ounces

*Commercial hydrochloric acid 20° Baume.

Calcium cyanide. Calcium cyanide is a fine powder which absorbs moisture when exposed to the air and releases hydrocyanic acid gas. It is scattered on the floor of the room being fumigated in amounts sufficient to supply the desired quantity of hydrocyanic gas. It has the disadvantages, as compared with Zyklon or HCN discoids, that it is difficult to estimate the quantity of gas that will be given off, and that the residue is poisonous.

Safety measures in the use of hydrocyanic acid. While the irritant and lacrimatory properties of cyanogen chloride gas serve to give warning of its presence, other safety measures must also be taken to prevent accidents. The men detailed as fumigators must be well trained and disciplined. Every man working with the gas should be equipped at all times with a gas mask the canister of which contains substances for neutralizing hydrocyanic acid gas. Each man should be thoroughly trained in the use of a gas mask and failure to use the mask on the slightest indication of danger should be punished by disciplinary action.

When all preparations for applying the gas have been completed, the person in charge should assure himself by inspection that no unauthorized persons are present, that all workers have gas masks, and that the exits are properly arranged.

After a gassed building has been opened, no one should be permitted to enter until all evidence of the presence of a lacrimatory gas has disappeared, as determined by the officer or noncommissioned officer in charge of the work.

Foodstuffs which have been exposed to hydrocyanic acid gas should not be issued for consumption until twenty-four hours after exposure.

Sulphur dioxide. While a considerable proportion of the rat population can be destroyed by sulphur dioxide, its low penetrating power renders it less effective than hydrocyanic acid gas. As compared with hydrocyanic gas, sulphur dioxide is much less dangerous to man and, where personnel trained in handling dangerous gases is not available, it will usually prove to be the most practicable agent for the fumigation of rat infested buildings. It cannot, however, be depended on to kill more than an average of 50 per cent of the rats in a building containing materials or articles under and in which the rats can hide.

The sulphur dioxide is generated by burning sulphur in a pan, iron pot, or other metal container. In order to lessen the fire hazard and to provide the necessary moisture in the air, the receptacle in which the sulphur is burned should be placed over a vessel containing water. Sulphur should be used in quantities of not less than three pounds per 1000 cubic feet of air space.

The building or room is prepared for fumigation by closing all windows and doors, except those to be used as exits, pasting heavy paper over all cracks and crevices through which the gas could escape, and, so far as practicable, arranging the contents so as to eliminate air pockets or other conditions which might interfere with the diffusion of the gas.

In the fumigation of large buildings or rooms, the sulphur should be distributed in a number of generators so that the maximum concentration will be quickly reached. The sulphur is moistened with a small quantity of alcohol and ignited, immediately after which all exits are sealed from the outside.

After a minimum period of six hours, or preferably from twelve to twenty-four hours exposure, the windows and doors are opened and the building thoroughly ventilated. No person should be permitted to enter the building until all evidence of the presence of sulphur dioxide has disappeared.

Fumigation of isolated burrows and harborages. Gas may be used to kill rats in their burrows or harborages if the conditions are such that the rapid escape of the gas can be prevented. The compounds used for this purpose may be solid or liquid, such as calcium cyanide or carbon disulphide, which volatilize to form gas after introduction into the space to be fumigated, or carbon monoxide may be introduced as a gas directly into a burrow or other space in which the rats harbor.

Calcium cyanide dust. Calcium cyanide dust gives off hydrocyanic acid gas when acted upon by the moisture in the air or soil. It may be used in the fumigation of small, more or less air tight spaces, such as rat burrows in dumps, around buildings, and elsewhere, or the rat harborages between walls, under floors, and in rubbish heaps.

The calcium cyanide dust is forced into a rat burrow or spaces which harbor rats by means of a small dusting pump equipped with a flexible hose outlet. The dust should not be used to fumigate the interior of a building. Spaces, such as those between walls or below the floors, should be dusted from the outside. In so far as practicable, all apertures from which the dust will escape from the fumigated space should be closed.

Both the dust and the gas are very poisonous in small quantities. The hands should be thoroughly washed after handling the dust or any objects contaminated with it. The cans containing

the dust should be opened and the pump should always be filled or operated out of doors.

Carbon disulphide. Carbon disulphide may be effectively employed to destroy rats in their burrows, where the burrows are in solid earth. A piece of cotton or cloth, or a ball of waste is saturated with about an ounce of carbon disulphide and packed down into the burrow with a stick or long tongs. In order to prevent the escape of the gas, the mouth of the burrow, all cracks and crevices, and the mouths of communicating burrows are occluded by filling with tamped earth.

Carbon disulphide is more efficient when used in damp earth or during wet weather.

Carbon monoxide. Rat burrows in dumps, around the exterior of buildings, or in other locations, may be fumigated and the rats killed by carbon monoxide delivered through the exhaust pipe of an automobile. Where the burrows are accessible, a flexible pipe or a rubber hose is attached to the exhaust pipe and the other end is passed into the burrow. The carbureter should be adjusted for a rich mixture. In gassing the average burrow, the engine should be allowed to run at moderate speed for at least ten minutes. The burrows and harborages treated in this manner should be made as airtight as possible by sealing the cracks and the openings of connecting burrows with earth.

MISCELLANEOUS CONTROL MEASURES

Certain breeds of dogs when trained to kill rats may prove valuable aids in reducing the number of rats in large warehouses, stables or storerooms. Fox terriers and Irish or Scotch terriers are the most efficient breeds for this purpose.

Cats will kill a few of the young rats but, as a rule, will not materially reduce the rat population.

Shooting may be effective in some instances in eliminating small numbers of rats from dumps and other out-of-the-way places.

RAT SURVEYS

Rat surveys are conducted to determine the presence of rats infected with plague or to delimit the areas harboring infected rats. Surveys may also be made for the purpose of estimating the degree of rat infestation in a building or area with a view to deciding upon the control measures to be employed.

Survey to determine presence of plague infected rats. If a rat survey is made for the purpose of determining if plague infected rats are present, the suspected area is trapped in order to obtain specimens which will represent a cross section of the rat population. The rats thus secured are sent at once to a laboratory for examination for evidence of plague infection. Usually, trapping should be continued until an infected rat is found or, if the area is within a town or thickly populated section, until from 30 to 50 rats have been examined for every 100 persons living in the area.

If an infected rat is captured, it is a strong indication that a number of other plague rats are present in the locality. The point where the infected rat was captured is considered as a center of infection. The trapping activities are extended to gradually increasing distances from this center until infected rats are no longer to be found and the circumference of the infected area is determined. The area thus mapped out may be subjected to intensive rat eradicative measures which progress from the circumference inward towards the center.

Survey to determine degree of rat infestation. Prior to instituting an anti-rat campaign in a military station or camp, a survey should be made to determine the extent of the rat infestation and should include the following factors:-

a. The location of burrows and harborages.

b. The kinds of food materials available to rats.

c. To what extent the food materials that are accessible to rats can be rendered inaccessible.

d. The kind of control measures that will probably be the most successful under local conditions.

As the rat instinctively seeks concealment, the degree to which a given building or area is infested must be determined by signs of the activities of rats rather than by the number that are to be seen. These signs consist of damaged food, the presence of rat runways as evidenced by tracks and marks of dragging

tails in the dust or by greasy appearing, discolored marks on woodwork made by the feet and tails of the rats, burrows and harborages, freshly gnawed wood, or rat excreta.

Organization of anti-rat campaigns. The results of a rat survey of a station or camp will indicate the kinds of control measures that should be instituted. These necessarily will vary according to the conditions but, given average conditions with moderate rat infestation, successful control can usually be established and maintained by reducing the food supply to a minimum and by rat proofing to eliminate harborages, followed by an intensive poisoning campaign with persistent and systematic trapping thereafter. Slight infestation may be controlled by protection of food materials and by poisoning. In any event, a definite and predetermined plan of action, trained personnel and constant supervision are necessary for success.

CHAPTER XX.

CONTROL OF INSECT-BORNE DISEASES

A disease is classified as insect-borne when a blood sucking insect is the only or is the usual agent by which the etiological organisms are transmitted from person to person or from an animal to man.

Malaria and bubonic plague may be considered as typical examples of insect-borne diseases. The causal organisms of malaria are transmitted from the blood stream of one person to the blood stream of another by the mosquito. The causative agents of bubonic plague are transferred from the tissues of an infected rodent to the tissues and body fluids of man by the flea.

An insect-borne disease may be transmitted by only one genus or, in some instances, by only certain species of a genus. Thus, as far as is known, dengue is transmitted naturally only by *Aedes egypti* and *Aedes albopictus* of the genus Aedes. Malaria is transmitted only by members of the genus Anopheles but can be transmitted by a number of species of this genus. On the other hand, relapsing fevers are transmissible by both human lice and ticks.

The insects which transmit the various insect-borne diseases are shown in the following table:

Transmitting Insect		Disease
Mosquitoes		Malaria. Dengue. Yellow fever. Filariasis (due to *W. bancrofti*).
Lice		Typhus fever. Relapsing fever. Trench fever.
Ticks and mites		Tularemia. Relapsing fever. Rocky Mountain spotted fever. Tsutsugamushi.
Flies	Chrysops	Tularemia.
	Chrysops	Filariasis (due to *Loa loa*).
	Glossinae	Trypanosomiasis.
Phlebotomus (midge, sand fly)		Pappataci fever. Leishmaniasis.
Fleas		Bubonic plague. Typhus fever.

Insects, particularly the house fly, may also be concerned in the transmission of other diseases, especially those belonging to the intestinal group, such as typhoid fever or bacillary dysentery. In such cases, however, the insect becomes a transmitting agent only by serving to transfer mechanically the causative organisms of the disease in question from the infected excreta to the food of man. Such diseases are not, therefore, considered to be insect-borne in the same sense that malaria and bubonic plague are insect-borne.

CLASSIFICATION OF DISEASE-TRANSMITTING INSECTS

The members of the animal kingdom are grouped into two great subdivisions, Protozoa and Metazoa. The Protozoa are unicellular or noncellular animals and the Metazoa are multicellular animals. These divisions are further divided into groups, phyla, classes, orders, families, genera and species. Other divisions may be made, such as suborders, subfamilies and sections.

Insects belong to the phylum Arthropoda. Arthropoda may be defined as invertebrate animals which are segmented and have

jointed appendages and a cuticular exoskeleton. The phylum Arthropoda is divided into the following classes:

Arachnida (ticks, mites, spiders).
Crustacea (lobsters, cyclops, shrimps).
Prototracheata (Peripatus).
Insecta (flies, mosquitoes, bugs).
Myriapoda (centipedes, millipedes).

Of the classes which form the phylum Arthropoda, the insecta and arachnida are of the greatest importance in the transmission of disease to man.

Classes are further divided into orders. The class Insecta is composed of about twenty orders, of which five are incriminated directly or indirectly in the transmission of disease. These five orders are as follows:

Diptera (flies and mosquitoes).
Anoplura (lice).
Siphonaptera (fleas).
Hemiptera (bugs).
Orthoptera (roaches).

To these may be added the order Hymenoptera (wasps, bees and ants) some of the members of which bite or sting man and are a source of discomfort.

The class Arachnida is composed of eleven orders of which only one, the order Acarina (ticks and mites), is known to transmit disease. The Scorpionida (scorpions) and Araneida (spiders) may also be the cause of discomfort to man and, in some instances, constitute a pest.

While the Arachnida are not insects, the diseases which they transmit are commonly classified as insect-borne diseases.

TRANSMISSION OF DISEASE BY INSECTS

The insect host of the infective agent of an insect-borne disease is primarily infected by biting a person or an animal who has, or is a carrier of, the disease in question, with the consequent ingestion of blood containing the infective agent. In certain of the insect-borne diseases, the infective agent is transmitted by the primary insect host through the egg stage to succeeding generations.

The infective agents are subsequently transmitted to man as a result of biting or an attempt at biting by the infected insect

host. In the transmission of some of the insect-borne diseases, the infected insect injects the organisms into the tissues of man in the act of biting, either in the secretion from the salivary glands or in material regurgitated from the digestive tract. Malaria is transmitted by the former and plague can be transmitted by the latter method. In other instances, the surface of the skin is contaminated by the feces or glandular secretions of the infected insect, or by the tissues and body fluids of an insect crushed on the skin. This infected material reaches the blood of the bitten person by being inoculated into the bite wound or through abrasions made by scratching or rubbing the bitten areas. The infective agents of certain of the insect-borne diseases, notably plague and relapsing fever, will pass through the unbroken skin.

Biological transmission. Some of the organisms which cause insect-borne diseases in man must pass through a stage of development in the body of the insect host before they can be transmitted to the human host. There is a biological relationship between the insect host and the parasite and this method of transmission is known as biological transmission. Malaria and filariasis are examples of diseases which are biologically transmitted.

The time required for the development of the parasite in the insect host constitutes the *extrinsic period of incubation.* The extrinsic period of incubation varies in length for different organisms, but is fairly constant for each organism.

The life cycle of certain of those organisms which are biologically transmitted includes a sexual and an asexual phase. The host in which the sexual phase occurs is known as the definitive host, while the one in which the asexual phase is passed is called the intermediate host. The transmitting insect or man may serve either as a definitive or an intermediate host. Thus, in the case of malaria, the sexual phase of the life cycle of the malaria parasite occurs in the Anopheles mosquito, which is, therefore, the definitive host, while man is the intermediate host. *Wuchereria bancrofti,* the etiological agent of filariasis, passes through the sexual phase in man and the asexual phase in the mosquito. In this case, man is the definitive host and the mosquito is the intermediate host.

Mechanical transmission. Where it is not necessary for the infecting organisms to undergo a period of development in

the insect host, biting insects may mechanically transfer the infective agents of diseases from person to person or from animal to man. Usually, the diseases which are transmitted mechanically by biting insects are those due to bacteria. Bubonic plague is the best example of an insect-borne disease which is mechanically transmitted, but any blood stream infection could, theoretically at least, be transmitted in this manner.

GENERAL PREVALENCE AND IMPORTANCE

Other factors being equal, the geographical and local prevalence of an insect-borne disease is governed by the distribution and prevalence of the insect host. Consequently, insect-borne diseases can prevail only in districts where the insect hosts are indigenous and environmental conditions are favorable for their continued existence. For example, those species of mosquitoes which are capable of transmitting disease can survive and propagate only under favorable climatic conditions and, consequently, mosquito-borne diseases are most prevalent in tropical and subtropical regions and in the warmer portions of the temperate zones. Conversely, louse-borne diseases occur most frequently in cold and temperate regions, as the conditions produced by cold weather favor propagation and dissemination of human lice.

Where the cycle of transmission includes an animal host of the infectious agent, or of the transmitting insect, the prevalence of the disease concerned is modified or entirely governed by the accessibility of the animal hosts. For example, bubonic plague occurs in man only when plague infected rodents are present, and Rocky Mountain spotted fever prevails only where suitable animal hosts are accessible to the transmitting tick.

Those insect-borne diseases transmitted by insects which are only incidentally or occasionally parasitic on man, including the diseases transmitted by mosquitoes, fleas or ticks, are not military diseases in the sense that a military environment, as distinguished from a civilian environment, facilitates their spread, or that their incidence is usually greater in a military population than in the civilian population generally. On the other hand, trench fever, typhus fever and relapsing fever are true military diseases in the sense that they tend to prevail to a much greater extent among troops than in civilian communities. This is due to the fact that the insect host—the human louse—is an absolute

parasite on man, and a military environment, especially under combat conditions, favors its continued propagation and dissemination. Consequently, of the insect-borne diseases, the louse-borne diseases are potentially the most dangerous to military forces.

GENERAL CONTROL MEASURES

Procedures for the control of insect-borne diseases are designed chiefly to control or destroy the insect hosts of the infective agents. Measures may be taken to control or destroy the animals which serve as hosts for the transmitting insects or as carriers of the causal organisms. In other instances, insect-borne diseases may be prevented by protecting man from the bites of infected insects, or by preventing human cases or carriers from infecting the transmitting insect hosts.

Control of insect hosts. The control or eradication of an insect host may be accomplished either by the destruction of the insect in some one of the stages of its life cycle or by so modifying the environmental conditions that breeding or the continued existence of the adults is prevented or inhibited.

Insect control measures generally are designed to take advantage of and utilize some characteristic or habit of the insect which renders it vulnerable to attack. In certain instances, control procedures may be successfully directed against the breeding places, while in other situations control can be most effectively accomplished by measures which destroy the insect in the adult stage or during some one of the developmental phases of its life cycle. For example, mosquitoes are controlled mainly by elimination of their breeding places and by destruction of the larval and pupal forms (Chapter XXI). The body louse is controlled by destruction of the egg, nymphal and adult forms, or by maintaining conditions, such as cleanliness, which are inimical to its propagation or continued existence (Chapter XXII).

Control of animal hosts. The control of those insect-borne diseases in which an animal serves as a reservoir of infection, or as the normal host for the transmitting insects, is effected primarily by the control of the animals concerned. Thus, the spread of bubonic plague is prevented or controlled by the destruction of the rodents which serve both as hosts for the fleas

and as carriers of plague bacilli. Rocky Mountain spotted fever is prevented by the control of the animals that serve as hosts for the transmitting ticks and, presumably, as carriers of the causal organisms of the disease (page 984).

MALARIA

(Intermittent fever, Remittent fever, Ague, Malarial fever)

Definition. Malaria is an infectious disease characterized by an intermittent or remittent fever, chills, profuse sweating, and, in the more chronic cases, by anemia, enlargement of the spleen and cachexia. In untreated cases, the course of the disease is ordinarily characterized by relapses and latent periods. Pernicious forms occur which are characterized by prostration and coma, and are frequently fatal.

Etiology. Malaria is caused by the proliferation in the blood stream of a protozoal parasite belonging to the genus *Plasmodium.* Four species of *Plasmodium* will cause malaria in man. *Plasmodium vivax* is the causative agent of benign tertian malaria, *Plasmodium malariae* of quartan malaria, and *Plasmodium falciparum* of subtertian (*estivo-autumnal, malignant tertian*). *Plasmodium ovale* causes a mild type of malaria clinically similar to the benign tertian form of the disease. *P. ovale* was first described by Craig in 1900 as occurring in the Philippine Islands. It has since been found in Africa by Ahmed Emin, Stephens and others.

Life cycle of the plasmodium. The life cycle of the malaria plasmodium consists of two phases, one of which, the asexual stage, is passed in the blood of man, and the other, the sexual stage, in the body of the Anopheles mosquito. While each of the four species differs morphologically from the others, they all develop in the same manner.

Man is the intermediate host of the plasmodium and the parasite reproduces in the human host by an asexual process known as *schizogony.* That part of the life cycle which takes place in the human host is known as the endogenous or asexual cycle or phase of development of the organism. The mosquito is the definitive host and the reproduction of the plasmodium in the mosquito is the result of a sexual process known as *sporogony.* The development of the plasmodium in the mosquito is known as the exogenous or sexual cycle or phase of the life cycle.

The *sporozoites*, which are the infective forms of the malaria plasmodia, are introduced into the blood of man by the Anopheles mosquito. The sporozoite enters a red blood cell and develops and enlarges into a schizont, which, as it approaches maturity, divides into a number of segments or merozoites. The red cell then ruptures and disappears and the merozoites are released into the blood plasma. The merozoites enter other red blood cells where development begins anew. The time required for schizogony and the number of merozoites in each schizont varies with, and is characteristic for, each species of the plasmodium. *P. vivax* divides into from twelve to twenty-four, usually about sixteen, merozoites and requires 48 hours for development. The schizont of *P. malariae* contains from eight to ten merozoites and reaches maturity in 72 hours. *P. falciparum* requires from 24 to 48 hours or more for its development to maturity. The schizont of *P. falciparum* contains from ten to thirty-two merozoites.

Schizogony tends to proceed at the same rate for all parasites of a given group, so that the merozoites are released from all the infected red cells at approximately the same time. It is generally considered that when this occurs, a toxin is released into the blood which is the immediate cause of the malaria paroxysm.

Not all, and probably only relatively few, of the merozoites survive to invade red cells. Nevertheless, in a recently infected person, or prior to a relapse in a chronic case, the number of invaded red blood cells gradually increases until a sufficient number of parasites are produced to cause the clinical symptoms of malaria.

Some of the merozoites which reach and invade the red cells do not develop into schizonts, but become the male and female forms of the parasite. These forms are known as *gametocytes* (*gametes*), the female being known as the *macrogametocyte*, and the male as the *microgametocyte*. The gametocytes develop in the red blood cells and when mature are infective for mosquitoes. The gametocytes of each of the three species of malaria plasmodia possess characteristic morphological features by which they can be differentiated from the others.

The gametocytes, male and female, in the peripheral blood of man are ingested by the female Anopheles. Sexual union occurs in the stomach of the mosquito, resulting in the development

of an organism known as the *zygote.* The zygote penetrates the stomach wall to just beneath the outer layer where it encysts and becomes the *oocyst.* The sporozoites develop in the oocyst and are liberated when the oocyst ruptures. Some of the sporozoites reach the salivary glands of the insect, in which they may be present in large numbers. When the mosquito bites man, the sporozoites are carried with the salivary secretion through the wound into the blood stream, thus completing the life cycle of the plasmodium.

The plasmodia can be transmitted to man only after a period of development in the body of the mosquito. This *extrinsic period of incubation* requires from 8 to 21 days, but varies to some extent with the species of plasmodium, and with atmospheric conditions. It has been shown experimentally that in quartan malaria the extrinsic period of incubation may be as long as from 36 to 40 days.

The development of the plasmodium in the mosquito and, therefore, the ability of the infected mosquito to transmit the infection, is influenced by the atmospheric temperature and humidity. The optimum temperature ranges from 72°F. to 86°F., and the development of the plasmodium is inhibited or prevented by a temperature of 60°F. or less. However, subjection to a continued low temperature does not necessarily destroy the parasite in the mosquito and development proceeds when higher temperatures again occur.

The infected mosquito can transmit the infection for a relatively long period and, under the usual conditions where it is relatively short lived, probably for its entire life span. However, if the infected mosquito lives long enough it eventually becomes noninfective. Apparently, it is not harmed by the presence of the plasmodia.

Incubation period. The incubation period of malaria in man (*the intrinsic incubation period*) is from six to thirty days. The length of the incubation period depends, within limits, on the degree of infection and varies to some extent with the species of the infecting plasmodia, and the susceptibility of the infected person. If the individual has had malaria and has developed a relative immunity or a tolerance to the infection, the incubation period may be greatly lengthened. It is generally considered that the incubation period for benign tertian malaria is from fourteen to twenty days, the average being about seventeen days.

For quartan malaria the incubation period is about twenty-eight to thirty days, and for malignant tertian from nine to fifteen days, the average being about twelve days. The incubation period for all types of malaria is shortened by heavy infections, or by fatigue, exposure to inclement weather or other depressing influences.

Susceptibility and immunity. Man is universally susceptible to infection with the malaria parasite, although the occurrence and severity of clinical symptoms may depend on or be influenced by factors which impair the physical fitness and resistance of the individual. Repeated attacks or a long continued infection apparently create a tolerance for the toxin of the parasites, but do not afford absolute protection against new infections nor against relapses of an existing infection. Boyd has found that infection with *P. vivax* produces an acquired immunity to the homologous strain of the parasite, and that a partial immunity may persist for at least three years, even in the apparent absence of a latent infection.

Prevalence and importance. The prevalence of malaria is governed by the prevalence of the insect host and by factors which favor or mitigate against infection of the insect host, or the development of the plasmodia in the tissues of the insect. Malaria prevails in tropical and subtropical countries, and in warm climates generally, between the latitudes of 60 degrees N. and 40 degrees S. It is most prevalent in the belt between 20 degrees S. latitude and 35 degrees N. latitude.

The seasonal variations in the prevalence of malaria are determined largely by the meteorological conditions which affect the breeding of the insect host. In the southern part of the United States generally, the incidence is the highest during August, September and October. In tropical regions, malaria may be most prevalent in either the wet or the dry season, depending upon the breeding habits of the transmitting mosquito in the particular locality concerned. In the American tropics, the greatest incidence occurs, as a rule, during rainy seasons when climatic conditions favor the propagation of the transmitting mosquitoes.

Because of the breeding habits of the Anopheles mosquito, malaria is essentially a disease of rural sections, rather than of cities or relatively densely inhabited communities. It prevails to a greater or less extent throughout the rural portions of the southern states, but the incidence varies greatly with the loca-

conditions which influence the prevalence of mosquitoes, or determine the effectiveness of control measures where such measures are employed. Malaria is endemic in Porto Rico, Panama and in certain parts of the Philippine Islands. There are no Anopheles mosquitoes in Hawaii and, consequently, there is no indigenous malaria.

During peace, malaria occurs among troops operating in localities where measures for the control of malaria cannot be or are not made completely effective. In malarious districts, such as, for example, the Panama Canal Department, the incidence of malaria is low among the troops that are stationed within the so-called sanitated areas or zones where mosquito control measures are effectively employed. In the great majority of instances, the malaria occurring among troops is contracted through exposure while on duty or on pass in civilian communities.

Malaria carriers. The mosquito can become infected only by biting a person who has the mature gametocytes of the malaria plasmodium in his peripheral blood. Such a person is known as a malaria carrier, or a gametocyte carrier, and may or may not present demonstrable clinical symptoms of malaria.

Gametocytes appear in the blood of man after several generations of schizonts have developed, usually in from seven to fourteen days or more after infection with the plasmodium. However, not all gametocyte carriers are necessarily infectious to the mosquito, for the reason that, in order to infect the mosquito, the concentration of gametocytes in the peripheral blood must be such that the blood meal ingested by the mosquito will contain both male and female forms.

During periods when the infection is latent, the gametocytes in the peripheral blood may be greatly reduced in number or they may disappear entirely. It is generally estimated that the chances of a biting mosquito becoming infected are remote unless the blood contains at least twelve gametocytes per cubic millimeter, or one gametocyte for every 500 leucocytes.

Transmission. The primary source of malaria in man is always the human gametocyte carrier and, in nature, the infection is transmitted from person to person only by certain species of Anopheles mosquitoes.

The transmission of malaria from person to person is, however, influenced and restricted by many factors in the life cycle of the transmitting mosquito and of the causal parasite, and, in

order for transmission to be completed, there must be a definite sequence of events which depend on the co-existence of a number of conditions. As a result of these restrictions, malaria ordinarily occurs only in endemic form, although epidemic prevalence is not infrequently attained where conditions are especially favorable for transmission of the infecting organisms.

The spread of malaria in any population depends within limits on, first, the number of Anopheles present which are capable of transmitting the plasmodium, second, the number of gametocyte carriers to which Anopheles can gain access, and third, the presence of persons who are not, for the time being, resistant or immune to the infection. The probabilities are that any one mosquito that bites a gametocyte carrier will not survive the hazards of its existence for the time required for it to become infective and thereafter find and bite another susceptible person. If only a few gametocyte carriers are present in a population, the chances are also remote that the relatively few mosquitoes that find and bite these persons, and thus become infected, will survive and transmit the infection to other persons.

Thus, in order for malaria to spread, there must be a numerical relationship between the number of sources of infection, that is, the number of gametocyte carriers, and the number of Anopheles capable of transmitting the plasmodia. A few mosquitoes will not, ordinarily, produce any considerable number of new infections, even though a relatively large number of gametocyte carriers are present, nor will a large number of mosquitoes ordinarily cause the disease to spread if there are but few carriers in the community.

Control measures. The control of malaria is based on the following procedures:

a. Control of the transmitting species of Anopheles mosquito.

b. Protection of man from the bites of infected mosquitoes.

c. Prophylactic treatment.

d. Thorough treatment of all cases and carriers of malaria.

e. Isolation of malaria carriers to prevent infection of mosquitoes.

The control of the transmitting mosquito is accomplished by the control of breeding and the destruction of the immature forms and adults. The procedures employed for this purpose are discussed in detail in Chapter XXI.

Prophylactic treatment. Prophylactic treatment consists of the administration of anti-malarial drugs in such quantities and at such intervals that the malaria plasmodia will be destroyed before they develop in sufficient numbers to produce clinical symptoms or to infect mosquitoes.

The term *prophylaxis,* as used in connection with the administration of anti-malarial drugs for the purpose of preventing the occurrence of clinical symptoms of malaria, does not mean the prevention of infection. Drug prophylaxis generally is actually the early treatment of malarial infection, or, in other words, a curative treatment of subclinical malaria. For many years quinine has been used throughout the world to prevent clinical malaria and, within limits with respect to length of time of exposure and degree of infection, this method has proven effective (*infra*). Within recent years atabrine and plasmochin have been used in lieu of or combined with quinine in the prophylaxis of clinical malaria (*infra*). It is in this sense that the term "prophylaxis" is used here.

Quinine prophylaxis. Quinine prophylaxis has been the subject of much controversy and dispute, but, nevertheless, it undoubtedly has a definite value and place in the control of malaria. Where troops are operating in situations where they will be exposed to the bites of infected mosquitoes, but where existing conditions preclude mosquito control, quinine prophylaxis can be employed to control the occurrence of the clinical manifestations of malaria.

Quinine prophylaxis does not prevent infection and probably does not, in the majority of instances, prevent the development of a certain number of parasites in the blood. It will not, in the presence of heavy infections or long continued or repeated exposure, prevent the occurrence of a certain number of cases of malaria. Quinine prophylaxis will, however, when properly administered, prevent a moderate number of plasmodia from developing to the point where they are present in the blood in sufficient numbers to produce clinical symptoms of malaria and thus incapacitate the individual for duty. To this extent, quinine prophylaxis will obviate non-effectiveness and keep men on duty who would otherwise be hospitalized for malaria.

Quinine kills the schizonts of all species of malaria plasmodia. It does not destroy the mature gametocytes of *P. falci-*

parum and is not effective in the sterilization of carriers or in preventing the infection of mosquitoes with this parasite. Quinine is a gametocide in benign tertian (*P. vivax*) and quartan (*P. malariae*) malaria.

Any one of several different methods can be employed in the administration of quinine prophylaxis. Usually, quinine sulphate is used. It may be given in daily doses of from 0.3 gram (5 grains) to 1.3 grams (20 grains), or it may be given once or twice weekly in from one gram (15 grains) to three gram (45 grains) doses. It should be remembered, however, that the purpose of quinine prophylaxis is to destroy the developing plasmodia as soon as possible after their introduction into the blood, and sufficient dosage should be used to accomplish this purpose. In giving quinine prophylaxis to troops, usually the best results will be obtained, under ordinary conditions, by the administration of daily doses of one gram (15 grains). In the presence of many infected mosquitoes, the dosage should be increased to 1.3 grams (20 grains) per day.

The quinine should preferably be given in tablet form, but may be given in solution or in capsules. The bitter taste of quinine in solution is objectionable and renders it difficult to secure the cooperation of the troops. Tablets are practically tasteless and will not usually be objected to on this score by the troops. Occasionally, quinine tablets may become more or less insoluble and the quinine will not be completely absorbed from the alimentary tract. When tablets are used, each lot should be tested for solubility. Capsules are tasteless and readily soluble, but they frequently become sticky and difficult to handle under field conditions.

In the administration of daily quinine prophylaxis to troops, the quinine should be given in one dose, preferably just before evening mess. The troops should be placed in formation and marched to a designated point and each man should be required to bring with him his canteen cup half full of water. Each man is then given the quinine and required to swallow it immediately under the supervision of an officer, preferably a medical officer. If necessary, because of the lack of officer personnel, the administration of the quinine may be supervised by noncommissioned officers, but they must be thoroughly reliable. Quinine should never be issued to troops to be taken without supervision.

The tendency for many men who are taking quinine to attribute to its effects any and all actual or imaginary ills will result in many of them neglecting to take the quinine unless its administration is officially supervised.

Quinine prophylaxis should be employed whenever there is danger that any considerable proportion of the troops will be bitten by infected mosquitoes. Troops operating in malarious districts, either for the purpose of training, the performance of peace time duties, such as mapping, or in the prosecution of war time activities, where adequate mosquito control measures cannot be utilized, should be given quinine prophylaxis. Where large numbers of Anopheles are present, troops in the field should, where practicable, be protected from the bites of infected mosquitoes by the use of bed nets, head nets and gloves, but these measures should be employed in conjunction with and not in lieu of quinine prophylaxis. Many species of Anopheles are crepuscular in their biting habits, that is, they bite freely during twilight, and for this reason, it is seldom that troops can be fully protected from infection by bed nets or similar measures.

On the other hand, the use of quinine prophylaxis as a control measure in a military organization is not ordinarily justified unless the troops are actually being exposed to the bites of a considerable number of Anopheles mosquitoes under conditions which indicate that many of the mosquitoes are infected. Troops object to taking quinine and the administration of quinine as a prophylactic measure usually has a more or less unfavorable effect on morale. Also, quinine in prophylactic doses may not, in all instances, prevent the production of gametocyte carriers who will serve to infect mosquitoes. Consequently, if, under existing conditions, it can be reasonably expected that only a few cases of malaria will develop if no quinine prophylaxis is given, these cases should be allowed to develop and then given proper treatment.

Where troops have been operating in a malarious locality and have been taking quinine prophylaxis, the daily administration of the quinine should be continued for at least two weeks after their return to sanitated areas or to localities where they are no longer exposed to infection. This procedure prevents the occurrence of many of the cases which would otherwise result from infections acquired during the last few days of exposure. Cases

which develop thereafter should be given suitable therapeutic treatment.

Quinine idiosyncrasy and cinchonism. Occasionally, but very rarely, an idiosyncrasy to quinine is exhibited, the symptoms of which may develop even after very small doses of the drug have been administered. It is usually manifested by severe vertigo, deafness, diarrhea and vomiting, impairment of vision and possibly temporary blindness, urticaria and, in some cases, hemoglobinuria.

Cinchonism is due to the toxic effect produced by large doses or the long continued administration of quinine. When troops are given quinine as a prophylactic measure in doses of from 0.6 to one gram daily over a period of weeks or months, usually a certain number of them will eventually present some evidence of cinchonism. The characteristic symptoms of cinchonism include headache, tinnitis, vertigo, gastric disturbances and skin rashes. These symptoms disappear rather promptly if the dose of quinine is reduced or its administration is stopped for a few days.

Atabrine prophylaxis. Atabrine is a synthetic compound which has been proven to have a definite place in the curative treatment of malaria. It destroys the schizonts of all forms of the malaria plasmodia and the gametocytes of *P. vivax* and *P. malariae.* A number of studies have been made with a view to the use of atabrine as a "prophylactic" in the same sense that quinine is used for this purpose. In most instances, subcurative dosage of 0.1 gram daily has been used, but the results obtained have not been conclusive. The cumulative effects and possibly toxic action of the drug preclude its administration over a long period of time (*infra*).

Plasmochin prophylaxis. Plasmochin is a synthetic quinoline derivative. It destroys the gametocytes of *P. falciparum,* but has little effect on the schizonts. Plasmochin has been used as a prophylactic, usually together with quinine, but the results have not been satisfactory. It has the major disadvantage that because of its toxic effects, its use must be closely supervised by a medical officer (*infra*).

Treatment of malaria as a control measure. Control of malaria by treatment alone requires that a large proportion of the cases of malaria that occur be so treated that they will not infect mosquitoes and thus serve as sources from which the

infection will be transmitted to other persons. This method of control has several major disadvantages. It is difficult, if not entirely impracticable, under the conditions usually prevailing in a military organization, or a civilian community, to find and treat a sufficient proportion of the gametocyte carriers to make this method of control effective. The drug or drugs used for treating the cases must destroy promptly the gametocytes of the species of malaria plasmodium involved. In new infections, treatment must be effective before there are a sufficient number of gametocytes in the peripheral blood to infect mosquitoes (*supra*). Where relapses or recrudescences occur, it is frequently impossible to institute treatment soon enough to destroy the gametocytes before mosquitoes are infected. Also, reinfection of the treated cases, and new infections, are apt to continue to occur as long as the population concerned is exposed to the bites of infected mosquitoes.

However, under suitable conditions in military organizations where only a relatively few cases of malaria occur and where adequate facilities are available for examining blood for malaria parasites, control of malaria by treatment can be accomplished, or treatment for the purpose of control may be a valuable adjunct to other control measures.

Malaria cases and carriers among civilians living adjacent to a military camp or station may serve as important sources of infection and their treatment may constitute an important phase of malaria control among the troops concerned.

Quinine. Quinine destroys the asexual forms of the parasite and thus cures or prevents the occurrence of acute symptoms of the disease. By preventing sporulation quinine also prevents the continued development of gametocytes.

While the continued administration of quinine inhibits or prevents the development of new broods of gametocytes, the gametocytes that were mature when treatment was instituted will remain in the blood until destroyed by the defensive mechanism of the tissues. Recent studies indicate that this period is probably not more than twenty days. Gametocytes do not develop in the blood until from one to three weeks after the initial infection and usually not until after the appearance of clinical symptoms. The prompt treatment of initial infections will, therefore, in many instances, prevent the production of the gametocyte forms.

Inadequately treated infections usually become latent with recurring relapses. Latent malaria may also occur without the patient presenting any of the classical symptoms of malaria. In latent malaria, schizonts are present in the peripheral blood of all cases, and gametocytes can be found by ordinary laboratory examination in from 40 to 50 per cent of the cases.

Relapses are due to continued sporulation of the parasite and development of the asexual forms until a sufficient number are present to cause clinical symptoms. Gametocytes are not concerned in the production of a relapse, but the continued sporulation also results in the production of gametocytes. Consequently, the prevention of relapses by adequate treatment is an essential factor in preventing the infection of mosquitoes.

In the treatment of initial, recurring, or latent malaria infections, some one of the several accepted methods should be employed. One such method consists of giving two grams of quinine daily in broken doses until the temperature remains normal for five or six days. Then 0.6 gram is given daily for eight weeks.

The short quinine treatment has recently been employed with success in the treatment of malaria in so far as the cure of the disease is concerned. From 15 to 18 grains of quinine are given daily until the fever subsides and the parasites are no longer present in the peripheral blood. Usually, the quinine is administered for from four to seven days and if relapses occur thereafter, the treatment is repeated. In the control of malaria by treatment, the short quinine treatment procedure has the disadvantage that it does not destroy the gametocytes of *P. falciparum*, and may not in some instances eliminate the gametocytes of *P. vivax* or *P. malariae*. It has the advantages of avoiding the prolonged administration of quinine required by the ordinary methods, and of being relatively inexpensive.

Atabrine. Atabrine is the most valuable of the synthetic drugs for the control of malaria by treatment. It is usually given in doses of 0.3 gram daily for five days. Atabrine kills the gametocytes of *P. vivax* and *P. malariae* and treatment with atabrine should, if indicated, be followed by a course of plasmochin, in order to destroy the gametocytes of *P. falciparum*. Atabrine has a cumulative action and its toxic effects are apparently enhanced when combined with plasmochin.

Occasionally, atabrine will produce a yellow discoloration of the skin due to the deposition of the dye in the skin. Mental disturbances have been attributed to atabrine but these conditions have been very rare. It has not been definitely determined that they are caused by the drug.

Plasmochin. Plasmochin has a selective action on the gametocytes of *P. falciparum,* and is much more efficacious than quinine, in so far as the rapid elimination of the gametocytes of *P. falciparum* is concerned. Plasmochin is, however, inferior to quinine in its effect on the schizonts of all species of the malaria plasmodium, and particularly those of *P. falciparum.* The administration of plasmochin alone may, however, be attended by toxic effects which are manifested chiefly by cyanosis due to methemoglobinemia. The toxic effects of plasmochin are less severe when plasmochin is combined with quinine to form plasmochin compound. Plasmochin compound is prepared in the form of a tablet containing 0.01 gram of plasmochin and 0.125 gram of quinine. Smaller tablets containing one-half of these amounts are also available. Other compounds, such as chinoplasmin, containing relatively larger quantities of quinine are available.

Isolation of cases and carriers. Malaria patients and carriers should be isolated in screened wards, rooms or tents in such a manner as to prevent the infection of Anopheles mosquitoes. Where patients are housed in tents, it may be necessary to use bed nets in lieu of screening. Isolation should be continued until the patient or carrier is no longer infectious to mosquitoes, that is, until gametocytes are no longer present in the peripheral blood in sufficient numbers to infect mosquitoes (page 846). In many instances, isolation need not be maintained for longer than the time required to cure the clinical manifestations of the disease. In some instances, as in the treatment of heavily infected carriers, it may be necessary to extend the isolation period for as long as three weeks.

DENGUE

(Break-bone fever, Dandy fever)

Definition. Dengue is an acute infectious disease, manifested clinically by an abrupt onset, severe malaise and depression, pain in the back and extremities, especially in the joints, intense postorbital and supra-orbital headache, anorexia, and a fever which is characterized by a period of remission on the third or fourth day which lasts for from twelve to thirty-six hours and is followed by a secondary rise in temperature. There is a leucopenia with polymorphonuclear reduction. A characteristic rash accompanies the secondary rise in temperature. Uncomplicated dengue is a non-fatal disease, but convalescence may be prolonged and accompanied by asthenia and physical and mental depression.

Atypical cases are common and frequently the secondary rise in temperature does not occur. The rash may be absent and, in many instances, the symptoms are mild and the disease is difficult to diagnose.

Etiology. Dengue is caused by a specific filterable virus which is present in the peripheral blood only during the first three days of the disease.

Incubation period. The incubation period of dengue varies from three to ten days. The usual period is five or six days.

Susceptibility and immunity. Man is universally susceptible to dengue. Apparently, neither age, sex nor race influences susceptibility, although native races of tropical and subtropical countries may exhibit a high group resistance because of acquired immunity.

One attack of dengue tends to confer immunity to the disease. Second attacks that can be diagnosed do occur, but are relatively rare and are less severe than primary infections. It is probable that, in most instances, the conditions which have been diagnosed as second attacks of dengue have been in reality due to some other infection. It may be that mild and undiagnosed attacks occur subsequent to the first attack and serve to increase the immunity to the disease.

Prevalence and importance. Dengue tends to occur as explosive epidemics and pandemics. The epidemic characteristics of dengue are due chiefly to the high susceptibility of

the non-immune individual and to the habits of the transmitting insect host, which is essentially domestic and lives in close association with man.

The distribution of dengue is limited geographically by the distribution of *Aedes egypti* and *Aedes albopictus* (page 910). It occurs throughout the tropical and subtropical regions of the world generally, and is common in the West Indies and the Orient. Wide-spread epidemics have occurred in the southern part of the United States.

Dengue is more prevalent in urban or thickly inhabited districts than in rural regions, due to the limited range and domestic habits of the transmitting mosquito.

While dengue is a non-fatal disease, it is, nevertheless, important from a military viewpoint because of its influence on the effectiveness of the individual and the potential danger of epidemics which would render entire units non-effective for considerable periods of time.

Transmission. Throughout the world generally, dengue is usually and most commonly transmitted by *Aedes egypti.* It has been found that *Aedes albopictus* is capable of transmitting dengue in the Philippine Islands.

The source of infection is the person having the disease, and, as far as is known, there are no human or animal carriers of the infection. The infectious agent is present in the peripheral blood of a dengue patient only during the first three days of the disease. The blood is infectious for mosquitoes for a few hours prior to the onset of the fever and for three days thereafter. The mosquito is most readily infected during the first and second days of the disease.

The mosquito does not become capable of transmitting the infection until after an extrinsic period of incubation which apparently lasts about eleven or twelve days. It is probable that variations in temperature, and possibly other environmental conditions, influence to some extent the length of time required for the development of the virus in the mosquito host.

As far as has been determined, the infected mosquito remains infectious for life and is not injured by the virus.

Dengue can occur in epidemic form only when there is a certain numerical relationship between the number of *Aedes egypti* (or *Aedes albopictus*), the number of cases and the number of non-immune individuals present in the community. The

reduction in numbers of any one of these factors to below a certain point (*the critical number*) retards or prevents the spread of the infection.

Control measures. The control of dengue and the prevention of dengue epidemics are based primarily on the control of the insect host (*Aedes egypti* or *Aedes albopictus*) (Chapter XXI).

Aedes egypti breeds by preference in or near human habitations and will remain in houses or barracks continually throughout its life span. It apparently prefers the blood of man to that of the lower animals and is a persistent and vicious biter. Because of these characteristics, the probabilities that a small number of *Aedes egypti* will become infected with and transmit the virus of dengue are much greater than the chances that an equal number of Anopheles mosquitoes will transmit malaria.

As *Aedes egypti* are daylight biters, the control measures designed to eradicate them from buildings occupied by troops should include not only barracks and quarters, but also messes, offices, storerooms, or other places where men work, but do not necessarily sleep.

The habits and characteristics of *Aedes albopictus* are similar to those of *Aedes egypti* and the same control measures are applicable.

Measures to prevent the infection of mosquitoes are essential and very important features of dengue control. When the disease is present in a command, or the troops are subject to exposure in neighboring civilian communities, any man complaining of illness should be regarded as a dengue suspect and treated as a dengue patient until proven otherwise. During the first three days of the disease, dengue patients should be thoroughly and completely protected from mosquitoes, either by bed nets or in properly screened wards or rooms from which all mosquitoes have been eradicated.

YELLOW FEVER

Definition. Yellow fever is an acute infectious disease, characterized by sudden onset, congested facies, severe headache, pain in the lumbar region, a moderately high fever and a slow pulse, jaundice, hemorrhages from the mucosa of the digestive

tract (*black vomit*), asthenia, and an acute nephritis. The case fatality rate varies greatly in different epidemics but is usually between twenty and thirty per cent. A remission stage, or "period of calm" with amelioration of all symptoms, may occur between the second and fourth day of the disease and is usually followed in from a few hours to a day or more by a period of reaction, during which the more severe symptoms occur. The disease may be mild and difficult to diagnose in children.

Etiology. The causal agent of yellow fever is unknown but is believed to be a filterable virus. It is present in the peripheral blood during the first three days of the disease.

Incubation period. The incubation period of yellow fever varies from two days or less to six days, but is usually between three and five days.

Susceptibility and immunity. Man is universally susceptible to yellow fever and susceptibility is apparently uninfluenced by age, sex or race. Native populations may exhibit a high group immunity to the infection, but this is believed to be due to individual immunity resulting from infection during childhood, and not to any racial characteristic.

One attack of yellow fever confers permanent immunity to future infections.

Prevalence and importance. Formerly great epidemics of yellow fever occurred in South America, Central America, the West Indies and in the United States. During recent years, due to the efficacy of control measures, the disease has prevailed only in endemic form, or as relatively limited epidemics, in certain sections of South America, and in West Africa. Yellow fever does, however, possess epidemic characteristics which render possible its spread to any region where a transmitting insect host is present (*infra*). Facilities for rapid transportation by airplane have increased greatly the danger of carrying the infection from districts where yellow fever is endemic in Central and South America to the southern part of the United States.

Typical yellow fever, as it occurred in the epidemics of the past, is essentially a disease of urban or thickly settled communities where the infection is transmitted from person to person by the highly domesticated mosquito, *Aedes egypti*. Recently, yellow fever has been found in sparsely inhabited districts of Brazil and Colombia under epidemiological conditions which preclude the transmission of the infection by the classical man-mosquito-

man cycle. This type of the disease is known as *jungle yellow fever* and occurs among persons working or living near a jungle or forest, and in the absence of *Aedes egypti.*

Jungle yellow fever is most prevalent in areas of partially cleared forests, and, frequently, individuals contracting the disease have been so isolated from others that transmission of the infection directly from person to person would have been impossible. The epidemiological characteristics of jungle yellow fever indicate that under the local conditions, the infection can be transmitted by some vector other than *Aedes egypti*, that there is an animal reservoir of infection or that the virus persists in invertebrate vectors for long periods of time, and that man is not an essential factor in the chain of transmission.

Sawyer, Soper and their co-workers have made surveys by means of the mouse protection test of many of the countries of the world to determine the prevalence of yellow fever during recent times. These workers found that the absence of immunity to yellow fever among young people, as shown by failure to obtain protective sera from this age group, indicated that the disease had not occurred in Panama or in the countries north of Panama during recent years.

Transmission. Typical yellow fever, as distinguished from jungle yellow fever, is transmitted from person to person by *Aedes egypti.* This species was formerly believed to be the only mosquito *capable* of transmitting the virus of yellow fever. It has been shown experimentally that other species of *Aedes* and *Eretomopodites chrysogaster* can transmit the infection from monkey to monkey. *Aedes egypti* is, however, the principal species by which the infection is transmitted from person to person.

From a practical control viewpoint, the yellow fever patient should be regarded as the source of infection, even though monkeys, or other animals, may constitute a reservoir of infection from which the virus of jungle yellow fever is transmitted to man. Human carriers have not been demonstrated.

The mosquito can be infected only by biting a yellow fever patient during the first three days of the disease. The infected mosquito can transmit the infection to man only after an extrinsic period of incubation of about twelve days. Mosquitoes remain infected for life and are apparently uninjured by the presence of the infection. The disease can also be produced by the

inoculation of virus through the skin and probably also by the passage of the virus through the unbroken skin.

Yellow fever can spread in a community only when there is a certain numerical relationship between the number of cases, the number of transmitting mosquitoes and the number of non-immune individuals. The reduction in number of either the sources of infection, the mosquitoes, or the non-immune persons below a certain point (*the critical number*) prevents or retards the spread of the infection.

Control measures. The measures employed for the control of yellow fever are principally those designed to control the transmitting mosquito, *A. egypti* (Chapter XXI.)

Convalescent serum. Convalescent serum has been used successfully to protect man where it was known that exposure to infection had occurred. Recent studies indicate that the protective bodies persist in the blood for a long time subsequent to an attack of yellow fever and that injections of blood serum obtained from persons who had the disease a number of years previously will confer passive immunity.

Active immunization. Several methods of conferring active immunity to yellow fever have been developed. Vaccination with mixtures of immune serum and the virus have been successful in protecting both experimental animals and man. Recently, Theiler and Smith have found that an active immunity to yellow fever can be produced, experimentally, by the subcutaneous injection of yellow fever virus which has been rendered relatively avirulent by prolonged cultivation in vitro.

TYPHUS FEVER

(Epidemic typhus, Endemic typhus, Brill's disease, Tabardillo)

Definition. Typhus fever is an acute infectious disease occurring as two types, which are differentiated clinically only by the relative severity of the symptoms.

Epidemic typhus (*typhus exanthematicus, classical typhus fever*), the more severe and virulent form of the Old World, is characterized clinically by a sudden onset, continued fever which terminates by crisis or rapid lysis on about the thirteenth or fourteenth day of the disease, general toxemia accompanied by stupor, delirium, and, at times, hallucinations, and a maculopapular rash

which appears on the fourth or the fifth day and tends to become petechial. The mortality rate averages from 15 to 25 per cent, but varies from 10 to 80 per cent in different epidemics.

Endemic typhus (*murine typhus*), or the New World form of the disease, which occurs endemically and sporadically in the United States, Mexico, and in other countries, differs clinically from the epidemic type only in that the symptoms are much milder. It also occurs in limited epidemics. In the ordinary case, there is a continued fever which terminates by lysis on about the fourteenth day. In the majority of such cases there are mental symptoms but these are less pronounced than in the epidemic form. The rash appears about the fifth day but tends to disappear in from two to three days without becoming petechial. Undoubtedly, there are many mild and even ambulatory cases which escape observation and diagnosis. Endemic typhus may cause death in the aged or when accompanied by complications. As nearly as can be determined, the case fatality rate among reported cases is between two and four per cent.

Etiology. Typhus fever belongs to a group of related diseases caused by *Rickettsia* transmitted from person to person, or from rodent to man, by arthropods. Of these diseases, typhus fever and Rocky Mountain spotted fever occur in the United States. Various typhus-like diseases are found in other countries, such as tsutsugamushi of Japan transmitted by mites, tropical typhus of the Federated Malay States which is thought to be transmitted by ticks and fleas, South African tick fever, and fievre boutonneuse of the Mediterranean regions. Theoretically, typhus fever, and the typhus-like diseases, may be primarily diseases of rodents, or of arthropods. It appears to be quite likely that the infection of man is accidental in the epidemiological progress of any one of these diseases among its rodent or arthropod hosts.

Rickettsia have their normal habitat in the tissues of arthropods. They are gram negative, bacteria-like organisms slightly less than one-half micron in length. They usually occur in pairs. They stain poorly with aniline dyes and can be stained to the best advantage with Giemsa or some one of the modifications of Romanowski's stain. They do not grow in artificial culture media.

Epidemic typhus fever. R. prowazeki is the causal agent of epidemic typhus fever. It exists intracellularly in human

lice which have fed on the blood of a typhus patient. In man, the organisms are present in the blood plasma and blood platelets and in the endothelial cells of the small blood vessels, where they occur singly or in masses.

Endemic typhus fever. Endemic typhus fever is also due to *Rickettsia* bodies, probably *R. prowazeki.* The organisms are found in the rat louse, *Polyplax spinulosus*, which transmits the infection from rat to rat, and in the rat fleas (*Xenopsylla cheopis* and *Ceratophyllus fasciatus*) which carry the infection from rat to rat and from rat to man (*infra*).

The virus of both epidemic and endemic typhus fever can be transferred by inoculation of the infectious blood from man to monkeys, guinea pigs, rats and mice, and the infection can be maintained in animals for months and years by successive inoculations.

The *Weil-Felix reaction* is an agglutination reaction in which the bacillus Proteus X_{19} (*Proteus vulgaris*) is agglutinated by the blood serum of a typhus patient. Proteus X_{19} was originally isolated from the stools and urine of typhus fever patients but is not the causal agent of the disease. The agglutination reaction does not appear until after the fifth day of the disease, after which it is present for several weeks, possibly for as long as two months. Maximum agglutination is usually obtained between the eighth and twentieth day after the onset of the disease. Agglutination in one-fortieth dilution in the presence of clinical symptoms is considered to be diagnostic of typhus fever.

A positive Weil-Felix reaction was formerly considered to be a specific diagnostic sign of typhus fever, but it is also positive in Rocky Mountain spotted fever.

Incubation period. The incubation period of typhus fever is usually about twelve days but may vary from five to twenty days.

Susceptibility and immunity. Man is susceptible to typhus fever without regard to age, sex or race. One attack apparently confers immunity to the disease, but there is considerable evidence that the protection is not permanent or absolute in all instances. Second, and even third attacks have been observed. However, it is probable that in most cases some immunity persists for a long period of time.

Prevalence and importance. *Epidemic typhus fever* occurs under environmental conditions which promote infestation

with lice. In armies, it occurs chiefly where troops are concentrated under combat conditions for relatively long periods of time. Formerly, typhus fever was prone to occur as extensive epidemics among besieged and besieging armies, while during the World War, the conditions brought about by trench warfare facilitated the spread of infected lice and, consequently, the transmission of typhus fever.

Among civilian populations, epidemic typhus fever occurs most frequently during famines, or during or following disasters or social upheavals which produce an environment in which lice will spread.

Geographically, epidemic typhus fever is essentially a disease of cold and temperate climates. It occurs in Europe, Asia and Mexico, but has not prevailed in recent years in epidemic form in the United States. It did not occur in epidemic form among American troops during the World War. At the present time, the most important typhus fever areas are Central Europe, Russia, Northern Africa, Northern China and Indo-China.

Epidemic typhus fever tends to prevail most extensively during the late winter and spring months, probably because the crowding and other environmental conditions induced by cold weather favor the propagation and dissemination of lice.

Endemic typhus fever, or New World type, occurs in the United States, especially in the southern and south-eastern portions and along the Atlantic Coast, and in Mexico. It has also been reported as occurring in other parts of the world, particularly in Australia, Africa and the Federated Malay States. In louse free communities, endemic typhus fever tends to occur endemically as sporadic cases and is more prevalent during the warmer months of the year.

Transmission. *Epidemic typhus fever*, as it occurs in armies, is transmitted by the human louse (*Pediculus humanus*, var. *corporis* and *capitis*) (Chapter XXII). While *P. humanus capitis* can transmit the infective agent of typhus fever, the disease is transmitted in the vast majority of instances by the body louse (*P. humanus corporis*). It may be that other insect vectors are capable of transmitting the virus of typhus fever, but the disease has not occurred in epidemic form among troops in the absence of infestation with lice. During epidemics, the infection is transmitted from case to case. Human carriers have not been demonstrated and probably do not exist. The infective agent

is not present in the discharges from the body and there is no evidence that the disease is transmitted by direct contact.

The virus is present in the peripheral blood and man is infectious to the louse during the entire course of the disease, from the onset until defervescence, and possibly until from one to two days after convalescence is established. The louse becomes capable of transmitting the infection to other persons in about five or six days after having bitten a typhus patient. Infected lice remain infected for life, but there is no evidence of hereditary transmission of the infection to their progeny.

The causative agent is present in the feces of lice and also in the body tissues. Louse excreta will remain infectious at room temperature for a period of about eleven days. The virus is destroyed by a temperature of 131°F. for 15 minutes.

Primarily, the louse introduces the virus into the blood of man by biting, but whether it is actually injected during the act of biting or is rubbed into the wound in the feces or the crushed tissues of the insect has not been definitely determined. The louse passes fecal material at frequent intervals while feeding and it is generally believed that, in most instances, the virus in the feces is inoculated through the puncture made by the bite of the insect or into abrasions resulting from scratching.

Endemic typhus fever is primarily a disease of rats and possibly of mice and other rodents. There is much evidence to show that the infection is transmitted from rat to rat by rat fleas and the rat louse, *Polyplax spinulosus,* and that rat fleas carry the infection from the rat to man. Epidemiological evidence indicates that the rat serves as an animal reservoir of infection. It is possible that should the etiological agent of endemic typhus fever be transmitted from rat to man in a louse infested community or military organization, transmission of the infection from person to person by human lice might readily occur and the disease assume the epidemic form.

Control measures. The control of *epidemic typhus fever* among troops is based on the control of lice. The habits and characteristics of human lice and measures for their control are considered in detail in Chapter XXII.

The control of *endemic typhus fever* depends mainly on the control of rats (Chapter XIX). Where a sporadic case occurs among troops, measures should be taken to insure that no blood

sucking insect (especially lice, fleas, or bedbugs) can gain access to the patient.

In the care of typhus patients, if conditions are such that absolute freedom from lice cannot be assured, all those who come in contact with the patient should wear louse proof clothing.

Immunization. Experimental studies have shown that active immunity can be created by vaccination with the killed virus of typhus fever. One such vaccine consists of a rich suspension of *Rickettsia* obtained by triturating the intestines of artificially infected human lice in a salt solution containing a small amount of carbolic acid. Zinsser and Castaneda have developed a vaccine containing large numbers of *Rickettsia* obtained by infecting rats intraperitoneally. There is experimental evidence indicating that this vaccine protects against endemic typhus fever, and to a less extent against the epidemic form of the disease.

Many studies have been undertaken with a view to producing passive immunity by the use of protective sera. Convalescent serum has been used with some success as a prophylactic. Zinsser and Castaneda were able to obtain protective serum by inoculating a horse with a long series of large doses of their vaccine. This serum protected guinea pigs against the virus of endemic typhus but gave no protection against the Old World virus.

The whole question of immunization, both active and passive, is still in the experimental stage.

ROCKY MOUNTAIN SPOTTED FEVER
(Tick fever, Black fever)

Definition. Rocky Mountain spotted fever is an acute, typhus-like disease, which is manifested by a characteristic rash, a continuous fever, which lasts from one week to ten days in uncomplicated cases, headache, and pain in the back and extremities. Rocky Mountain spotted fever resembles typhus fever in many of its clinical aspects. The rash of Rocky Mountain spotted fever is relatively much more severe than that of endemic typhus fever. A maculopapular and sometimes a petechial eruption appears about the third or fourth day. As a rule, the eruption appears first on the wrists, ankles and back and spreads to the face and other parts of the body. The Weil-Felix reaction (page 862) is positive in the majority of Rocky Mountain spotted fever cases.

Etiology. The Rickettsia organism (*Dermacentroxenus rickettsi*) is generally considered to be the etiological agent of Rocky Mountain spotted fever. The causative agent is carried by wild rodents, and transmitting ticks (*infra*) constitute an arthropod reservoir of infection.

Incubation period. The incubation period of Rocky Mountain spotted fever is from two to twelve days, usually from three to seven days.

Susceptibility and immunity. There is no natural immunity to Rocky Mountain spotted fever and persons of all ages and both sexes are susceptible. One attack confers permanent immunity to the disease.

Transmission. The infective agent of Rocky Mountain spotted fever is transmitted accidentally from animal to man by the wood tick, *Dermacentor andersoni*, and the dog tick, *Dermacentor variabilis*, and possibly related species. The tick may become infected in either the larval, nymphal or adult stage of its life cycle and transmit the infection to the succeeding stage. The infected female transmits the infection through the egg stage to her progeny. The inherited infection can be transmitted to man. The life history of ticks is considered in Chapter XXIII.

Rocky Mountain spotted fever occurs as a mild enzootic infection among the wild rodents that serve as hosts for the larval and nymphal forms of the tick. Various species of squirrels, rabbits, prairie dogs, woodchucks and badgers are susceptible to the infection. It is probable that the Columbian ground squirrel (*Cittelus columbianus*) and rabbits are the most important animal hosts of the virus and constitute the principal animal reservoir of infection. The infective agent is transmitted from rodent to rodent by wood ticks and dog ticks (*supra*) and also by the rabbit tick, *Haemaphysalis-leporis-palustris.* Cattle, horses, and the larger animals generally, are not infected in nature, but as they are the normal hosts for the adult tick they play an essential role in the maintenance of the arthropod host and therefore in the dissemination of the virus.

Prevalence and importance. The geographical distribution of Rocky Mountain spotted fever is restricted to certain definitely localized foci of infection in which the transmitting ticks are found. It was first reported as occurring endemically in local areas in Montana, Wyoming, Idaho, Washington, Oregon, Utah, Nevada, California, North and South Dakota and Nebraska.

More recently the disease has been reported from many other localities, including eastern, southern and mid-western states. There are, however, many sections where the ticks are prevalent, but the disease does not occur.

The fatality rate varies greatly with the locality. The disease as it occurs in the Bitter Root Valley in Montana has a fatality rate of about 80 per cent. In the Snake River Valley and on the dry, sage brush plains, the fatality rate varies from less than 5 per cent to 20 per cent. In the eastern states, it is about 25 per cent.

The seasonal prevalence of the disease corresponds to the seasonal activities of the tick and is the greatest during the spring and early summer months.

Control measures. The control of Rocky Mountain spotted fever is based on the control of the transmitting tick and its animal hosts (page 984). Infection of the individual can be prevented by avoidance, during the spring and summer months, of areas which are known to be infested with infected ticks. Protection is also afforded by clothing which will make it difficult for the tick to gain access to the body, and by the prompt removal of all ticks from the clothing and body.

Immunization. A vaccine has been prepared from the ground viscera of infected ticks which affords a considerable degree of protection from the disease. It is administered subcutaneously in doses of one c.c. each. Usually, two or three doses are given at five day intervals. The degree and duration of the immunity produced by the vaccine has not as yet been fully determined. Apparently, rather high immunity is conferred when vaccination is repeated each year before the beginning of the tick season. All persons who enter a tick infested region should be vaccinated.

TRENCH FEVER

(*Shinbone fever, Trench shin*)

Definition. Trench fever is an acute infectious disease, characterized by sudden onset, recurrent fever, prostration, pain in the muscles and in the regions of tendon attachments and periosteal surfaces, particularly over the tibiae and bones of the forearm, frontal headache with severe retrobulbar pain and conjunctival congestion, an erythematous, macular eruption which

is usually most pronounced on the chest, abdomen and back, and enlargement of the spleen. Relapses tend to occur over long periods of time, and the disease may become chronic or there may be a prolonged convalescence during which the most prominent symptoms are neurasthenia and cardiac irritability. Trench fever is non-fatal.

Etiology. Trench fever is a louse-borne disease. It is generally believed that trench fever is caused by *Rickettsia* (*R. pediculi, R. quintana*), or that Rickettsia bodies are intimately associated with the causative virus. Rickettsia occur extracellularly in the lumen of the intestinal tract of the infected louse. In man, the infective agent is present in the blood and is excreted in the urine and saliva.

Trench fever was first reported as occurring among troops engaged in trench warfare and was, for this reason, called trench fever. Trench warfare favors the spread of lice among troops, but the conditions produced by trench warfare are not otherwise concerned in the etiology or transmission of trench fever. The disease might occur in any situation where the troops are infested with lice.

Incubation period. The incubation period of trench fever, when the disease is transmitted naturally by the louse, is from fourteen to thirty days, usually between two and three weeks. In experimentally produced infections, the incubation period varies from five to thirty days.

Susceptibility and immunity. It is probable that susceptibility is universal, though negroes may be somewhat less susceptible than members of the white race. Susceptibility is, apparently, uninfluenced by the physical condition of the individual.

It has not been definitely determined whether or not an attack of trench fever produces immunity to future attacks. Apparent reinfections may be relapses of a previous attack.

Prevalence and importance. Trench fever is essentially a military disease. It was first described in 1915 as occurring among British troops. While trench fever has not been reported as prevailing in civilian communities either before or since the World War, it is thought that actually the disease was endemic in Russia and was subsequently carried to all parts of the front by German and Austrian troops. It eventually became prevalent in all major armies, except the American army. There were 901 cases reported as occurring among

American troops, but it is probable that the actual number was considerably larger and that many cases were not diagnosed. The disease assumed serious epidemic prevalence in the British and German armies. It is estimated that approximately one-third of all sickness in the British army during the World War was due to trench fever.

While trench fever is non-fatal, it is, nevertheless, of great military importance because of the long period of disability it produces. The frequent relapses, and the fact that a relapse can be provoked by physical exertion for some time after apparent recovery, entail long absences from duty. In the presence of heavy infestation with lice, trench fever may become widespread among troops in the combat zone and seriously impair the combat efficiency of an army.

Transmission. During an epidemic of trench fever, the infection is, in practically all instances, transmitted from person to person by the body louse (*Pediculus humanus corporis*). The infection can be transmitted by *P. humanus capitis* (head louse). The disease can also be communicated directly from one person to another by inoculation of infected urine, and possibly by the saliva, through abrasions in the skin or mucous membranes, but, under natural conditions, these agencies are rarely involved in the transmission of the disease. The primary source of infection is the trench fever patient. Healthy carriers of the disease have not been shown to exist. The patient is infectious to lice from two days after the onset of the disease, and probably earlier, throughout the acute stages and recurrences until recovery is complete. It has been demonstrated that a patient having the disease in a chronic form is infectious to lice, and, in one instance, was infectious for as long as 443 days.

A period of from seven to ten days elapses after the louse has bitten an infected person before it can transmit the infection to another person. Experiments have shown that the louse remains infected for as long as twenty-three days, and probably for life.

The feces of the louse are highly infectious and the virus in dried excreta of infected lice remains virulent at room temperature for at least as long as four months. The virus will also retain its virulence in the dried urine of trench fever patients for a period of several weeks.

The virus of trench fever is heat resistant and will survive for thirty minutes or longer at a temperature of 131°F. It is, however, destroyed by exposure for thirty minutes to moist heat at a temperature of 158°F. Consequently, a temperature which is sufficient to destroy lice and their ova (131°F.) (page 960) will not disinfect clothing contaminated with the excreta of infected lice or with the urine or sputum of trench fever patients.

The causative agent of trench fever is introduced into the blood by inoculation of louse excrement through the wound made by the louse in biting or through abrasions resulting from scratching. The crushed tissues of an infected louse also contain the virus and may serve to carry the infection into a bite wound or an abrasion. It has been shown experimentally that the virus may be injected by the louse during the act of biting.

Control measures. The control measures for trench fever are basically the same as for typhus fever (page 864) and depend on the control of lice (Chapter XXII). As the virus of trench fever is contained in the urine and saliva, the necessary precautions should be taken to prevent the transmission of the infection to hospital attendants by direct contact. Care should be exercised in handling the body discharges so that none of the material comes into contact with the skin, through which it might be inoculated. All clothing and bedding used by the patient should be thoroughly disinfected with steam or with a disinfectant solution, such as a two or three per cent cresol solution. Where steam is used to disinfest and disinfect the clothing and bedding, the methods employed should be such that the temperature in all parts of the material being treated will be maintained at or above 160°F. for at least thirty minutes. Articles which cannot be disinfected with steam, such as shoes or belts, should be immersed in a disinfectant solution.

RELAPSING FEVER

(European relapsing fever, African tick fever, Recurrent fever)

Definition. Relapsing fever is an acute infectious disease, or group of closely related fevers, the most pronounced characteristic of which is a recurrent fever with a definite intervening period of apyrexia. The onset is sudden, accompanied by a chill and followed by a rapid rise in temperature,

headache, pain in the back and joints, a macular eruption appearing usually on the neck, trunk, forearms and thighs and, in severe cases, delirium or stupor. In from four to seven, usually five or six days after the onset, the first paroxysm terminates by crisis. The temperature falls to normal or subnormal, all symptoms disappear and there is apparent recovery. The period of apyrexia lasts for from six to nine days, after which the first relapse occurs. The first relapse is accompanied by symptoms which are similar to and may be more severe than those of the original paroxysm. In most instances, the first relapse is followed by permanent recovery. A second relapse occurs in about one-third of the cases, but is usually shorter and less severe than the first relapse. Third and fourth relapses may occur but are relatively rare.

Etiology. The various forms of relapsing fevers are caused by closely related spirochetes, which are morphologically indistinguishable and can be differentiated only by their biological characteristics. *Treponema recurrentis* (*Borrelia recurrentis*) is the cosmopolitan type and is generally considered to be the cause of the relapsing fever of Northern Africa, Europe, North America, and Asia. *Tr. duttoni* is regarded as the causative agent of the relapsing fever of Central Africa, and *Tr. venezuelense* and *Tr. neotropicalis* as the cause of the relapsing fever occurring in Colombia, Venezuela and Panama.

The spirochetes are present in large numbers in the peripheral blood during the acute stages of the disease but are absent during the intervals between relapses. They are present in blood from hemorrhages, in the saliva and, possibly, in the perspiration and tears. The spirochetes can be rubbed through the unbroken skin or mucous membrane. They are killed by exposure to a temperature of 120°F. for thirty minutes. They are also quickly destroyed by ordinary chemical disinfectants.

Incubation period. The incubation period of relapsing fever varies from three to ten or twelve days, but is usually from five to seven days.

Susceptibility and immunity. Susceptibility to relapsing fever is general for all ages and races. An attack confers immunity which is, however, usually of short duration. Second attacks may occur within a few months or a year of the first attack. Second attacks are usually less severe than primary infections.

Prevalence and importance. As relapsing fever occurs in epidemic form only where insects, especially lice or ticks, can gain access to man in considerable numbers, it follows that the disease tends to prevail only under insanitary conditions. Louse-borne relapsing fever is, like other louse-borne diseases, a disease of considerable importance to military forces during war. It was not, however, generally prevalent among the World War armies, although rather extensive epidemics occurred in the Serbian and Turkish armies.

Louse-borne relapsing fever tends to be most prevalent in temperate and colder climates and the incidence is the highest during the colder months of the year. There is no variation in seasonal prevalence of tick-borne relapsing fever, except as the activities of ticks are influenced by seasonal changes.

Transmission. The person having the disease is the primary source of the infection. The existence of human carriers has not been demonstrated. Rats and mice can be infected with the spirochetes and may be factors in the transmission of the infection.

The human louse and numerous species of Ornithodorus ticks are the principal insect vectors. As the infection can be mechanically transmitted directly from person to person, it is possible that other blood sucking insects, such as the bedbug, flea or biting flies, may serve to transfer the infection mechanically.

Louse-borne relapsing fever has prevailed principally in Europe, Northern Africa, Asia and North America and tends to occur in epidemic form in lice infested communities or military organizations. Where the infection is tick-borne, as it is in Central and South America, Central Africa and in some parts of Asia, the disease occurs endemically as sporadic cases or limited epidemics.

When the louse ingests blood from a relapsing fever patient, the spirochetes are present in the intestinal tract for a short time but disappear within twenty-four hours. Thereafter, no spirochetes are visible in the body of the louse until between the seventh and tenth day after infection, when they reappear in the body cavity and the body fluids.

The louse can transmit the infection for a few hours after it has fed on infected blood. It then becomes non-in-

fectious and remains so for two days or more. After this time it can transmit the infection and is most infectious on about the sixth or seventh day, even though it contains no visible spirochetes at that time.

The tick is apparently capable of transmitting the infection shortly after having fed on infected blood and remains infectious thereafter for as long as eighteen months. In the tick, the infection is transmitted through the egg stage to succeeding generations.

It is generally believed that neither the tick nor the louse can transmit the infection by injection during the act of biting. The infective organisms are present in the secretions of the coxal glands and the excretions from the Malpighian tubules of the tick. This infective material is deposited on the skin near the wound produced by the bite of the tick and is subsequently rubbed or scratched into the wound or abrasions, or through the unbroken skin. Where the disease is transmitted by lice, the spirochetes are probably always transmitted from the louse to man in the material derived from the body of the louse which has been crushed on the skin.

The infection may also be transmitted by inoculation or by passage through the unbroken skin of the causal agents contained in the blood or saliva of the patient during the acute stages of the disease.

Control measures. The control of relapsing fever is based primarily on the control of the transmitting insect (Chapters XXII and XXIII). Tick infested huts and native houses should be avoided as sleeping quarters or billets. Where relapsing fever occurs in an organization, measures should also be taken to eradicate all bedbugs and fleas from barracks or quarters.

Salvarsan and its allied compounds have a specific action on the spirochetes of relapsing fever. Treatment as a control measure serves to prevent the infection of transmitting insects.

In the treatment of relapsing fever patients in hospital, care should be exercised to prevent the direct transmission of the infection to the attendants by infected blood or saliva. The clothing used by the patient should be disinfected with steam or a two per cent cresol solution.

PLAGUE
(*Pestis, Black death*)

Definition. Plague is an acute infectious disease which occurs primarily in rodents and secondarily in man. Plague occurs in man in two principal forms—bubonic and pulmonary. The *bubonic type* is usually manifested by a rather sudden onset, high fever, marked toxemia and prostration, and a characteristic, painful adenitis (buboes), which, in most cases, appears first in the groin and less commonly in the neck and axillae.

The fatality rate averages about 75 per cent. However, where extensive epidemics occur, the mortality varies with the social status of the individual. It is usually about 25 per cent among members of the white race, and from 75 to 95 per cent among natives. A mild form, *pestis minor,* is occasionally seen in which all symptoms are mild and transient and death rarely occurs.

Pneumonic plague is characterized by extreme toxemia and prostration, hemorrhagic sputum, and a more or less extensive bronchopneumonia. Death usually occurs within three or four days and the mortality is practically 100 per cent. Pneumonic plague may be primary or it may be secondary to the bubonic type.

Primary *septicemic plague* is not a distinct type of the disease but results from an overwhelming blood stream infection which causes death before either the symptoms of the bubonic or the pneumonic type develop. Septicemic plague may be secondary to either the bubonic or pneumonic type.

Etiology. Plague is due to *Pasteurella pestis* (*Bacillus pestis*). The disease occurs as an enzootic or epizootic infection, principally among rats but also among other rodents, especially the ground squirrel of California (*Citellus beecheyi*), and the tarbagan (*Arctomys bobac*) of Central and Northern Asia and Siberia. It also occurs in mice and other animals, but these do not ordinarily serve as sources of infection for man. Ordinarily, the disease is transmitted to man from plague infected rodents, usually through the medium of fleas but occasionally by contact and direct inoculation.

Incubation period. The incubation period of plague varies from two to ten days but is commonly from three to seven

days. The incubation period is usually shorter in the pneumonic than in the bubonic type.

Susceptibility and immunity. Susceptibility to plague is universal for all races and ages. One attack confers permanent immunity to future attacks. Second attacks may occur but are relatively rare.

Prevalence and importance. Plague tends to prevail in epidemic form, the extent of the epidemic depending largely on the degree of control exercised over the animal host. Generally, human cases of plague appear only after there has been an extensive epizootic of the disease among the rats or other rodent hosts of the community.

Geographically, plague is widespread over the world. As the rat is the usual animal host, plague outbreaks occur most commonly in seaport communities and it is probable that plague is enzootic among the rats in most of the large seaports of the world, except possibly those where extensive rat control measures have been undertaken. Plague is at the present time enzootic among the ground squirrels in California and the infection has been transmitted from squirrels to man, resulting in the sporadic occurrence of human cases.

Extensive or persistent epidemics of bubonic plague are more or less restricted to warm climates where the mean atmospheric temperature favors the activity of the transmitting flea. Pneumonic plague is essentially a disease of cold climates where environmental conditions promote crowding and the transmission of respiratory infection.

Plague follows trade routes, especially under conditions which facilitate the movement of rats and their food supplies, such as grain. Consequently, it is not an important military disease under the conditions of modern warfare and has never become prevalent in modern armies.

Transmission. Bubonic plague is transmitted from rodents to man by the flea. As rats constitute the chief animal host, the rat fleas, *Xenopsylla cheopis* and *Ceratophyllus fasciatus*, are the principal insect vectors. Certain of the species normally parasitic on other rodents will also transmit plague infection to man. While each species exhibits a preference for its particular host, those infesting plague infected animals will bite man when forced to do so by hunger or when they are accidentally transferred from their normal host to man. When the rat dies,

the fleas leave the carcass to seek new hosts, and as the rat population decreases the danger of infected fleas being driven by hunger to attack man increases. Ordinarily, therefore, plague is relatively widespread among the rats before human cases occur.

The infection may become chronic in rats and these animals then serve as carriers of the infection. Rats may also survive the infection so that a considerable proportion of the rat population of a given community may be immune and an epizootic is maintained only by the introduction of new arrivals or young rats.

The blood of the infected rat contains enormous numbers of plague bacilli and, consequently, fleas are readily and heavily infected. The bacilli remain viable and multiply in the alimentary tract of the flea and may be present in sufficient numbers to obstruct the proventriculus. The transmission of *Past. pestis* by the flea is mechanical and no developmental cycle occurs in the insect. The flea is capable of transmitting the infection immediately after feeding on infected blood and for a number of days, probably twenty or more, thereafter.

The flea regurgitates the bacilli into the wound during the act of biting. The bacilli are also passed in the feces of the flea and rubbed or scratched into the wound, or through the unbroken skin.

Bubonic plague is most apt to prevail in epidemic form during warm weather when the mean temperature favors the reproduction and activity of the flea. A mean temperature below 50°F. inhibits the activity of the flea and tends to prevent the spread of plague. A mean temperature of 85°F. or higher, especially if the humidity is low, likewise prevents the spread of the disease by inhibiting the activity of the flea.

Pneumonic plague may occur secondarily to bubonic or septicemic plague and is thereafter spread by contact between persons in the same manner as any other respiratory disease (page 29). The sputum contains plague bacilli in large numbers and crowding or close contact between individuals is an important factor in the transmission of the infection.

Control measures. The control of plague is chiefly a question of *preventing* human cases by rat control measures, or, if other rodents are concerned, their control by suitable procedures. The control of rats is considered in Chapter XIX. The

control of fleas, as distinct from the control of their animal hosts, is discussed on page 985. The control of squirrels is accomplished by means of poisoning and gassing with carbon disulphide (page 833), together with such auxiliary measures as shooting and trapping.

The danger of transmitting the infection by contact between persons is always to be considered in the control of human cases. While a case of bubonic or septicemic plague cannot transmit the bacilli as long as the buboes remain unopened, nevertheless, there is always danger of pulmonary involvement and transmission of the organisms in the secretions from the respiratory tract.

A case of plague of any type should be immediately isolated and all non-immune contacts should be quarantined for ten days. Contacts should be physically examined by a medical officer at least twice daily and any man showing a rise in temperature, an increase in the pulse rate, or headache should be regarded as a suspect and isolated. Usually, in pneumonic plague, a slight rise in temperature, with a rapid soft pulse and headache, occurs about twenty-four hours before coughing begins. During this stage, the patient is, as a rule, non-infectious and, if isolated at this time, he will not transmit the disease to others.

In the care of plague patients, every possible precaution should be taken to prevent the dissemination of the infection. All persons who will come in contact with plague patients should be immunized. Hospital attendants should wear heavy gauze or muslin face masks and goggles while working with patients having pneumonic plague. Rubber gloves should be worn while handling any article which might be contaminated with infected sputum or discharges from buboes. Measures should be taken to insure that all blood sucking insects are denied access to plague patients.

Past. pestis is killed in a few hours by exposure to sunlight but apparently it may, under favorable conditions, live for weeks or months on clothes, blankets or other textile fabrics. All clothing and bedding used by plague patients should, therefore, be disinfected by steam or burned. Rooms or wards which have been occupied by pneumonic plague patients should be thoroughly cleansed with a disinfectant solution and aired for forty-eight hours before being used for other purposes.

Immunization. Haffkine's vaccine, which consists of killed cultures of *Past. pestis,* affords a degree of protection against

plague infection. One or two doses are given and the immunity conferred lasts two years or longer. The reactions are frequently quite severe. Where plague occurs or threatens to occur among troops, all troops who might be exposed to the infection should be given the vaccine. However, vaccination alone without other control measures cannot be depended upon to prevent a threatened epidemic of plague.

An anti-plague serum (*Yersin's*) is available and may be used to produce a passive immunity or in the treatment of cases. It is prepared by injecting horses with killed cultures of plague bacilli followed by injections of the living organisms. The anti-plague serum may confer protection in some instances, but the results have not been generally satisfactory.

TULAREMIA
(*Deer fly fever, Rabbit fever*)

Definition. Tularemia is an acute specific disease of which there are two types—the *glandular* type and the *typhoid* type. The *glandular* type is characterized by a primary ulcer, or by conjunctivitis, painful swelling of the regional lymph glands, fever of two or three weeks duration, weakness and prostration. The *typhoid* type differs from the glandular type only in the absence of ulceration and glandular involvement. In both types the onset is sudden and convalesence tends to be prolonged. The fatality rate is between three and four per cent.

Etiology. Tularemia is caused by *Pasteurella tularensis* (*Bacterium tularense*). It is primarily a disease of animals, especially of rabbits. It is transmitted to man from animals principally by inoculation, but also by blood sucking insects, notably ticks, *Dermacentor andersoni* and *D. variabilis*, and the biting fly, *Chrysops discalis*. The infection can also be transmitted by the stable fly (*Stomoxys calcitrans*), by the bed bug (*Cimex lectularius*) and the squirrel flea (*Ceratophyllus acutus*). Tularemia also occurs in the California ground squirrel (*Citellus beecheyi*) and meadow mice, and has been reported as occurring in sheep. House mice, coyotes, gophers, guinea pigs and certain species of monkeys are known to be susceptible. In Norway and Russia, water rats have been found to be infected with *Past. tularensis*. Apparently, the jack rabbit, cotton tail and snow

shoe rabbits constitute the natural animal reservoir of infection in the United States.

In man, the organisms are present in the blood from early in the course of the disease until about the end of the second week. The agglutination test becomes positive during the second week and remains positive for a long period of time, a number of years, thereafter. Cross agglutination has been observed with *Brucella abortus* and *Brucella melitensis.*

In rabbits, infection with *Past. tularensis* produces a fatal bacteremia with involvement of the lymph glands, liver and spleen. The liver and spleen present a characteristic acute focal necrosis and are spotted with numerous small necrotic areas. About one per cent of market rabbits examined have been found to be infected.

Incubation period. The incubation period of tularemia in man is from one to nine days, usually about three days.

Susceptibility and immunity. Man is highly susceptible to the disease. One attack confers permanent immunity to future attacks.

Prevalence and importance. Tularemia is wide spread in the United States and has been reported from Japan, Russia, Norway, Sweden and Canada. It has recently been reported from Central Europe and Turkey. The seasonal prevalence varies with the opportunities for man to make contact with infected animal and insect hosts. In the eastern part of the United States, where rabbits are protected by game laws, the greatest incidence occurs during the autumn months when rabbits may be legally killed. In the west, where rabbits are not protected by law, transmission of the infection from rabbit to man tends to occur most frequently during spring and summer months. Where the infection is transmitted to man by the tick, most of the cases occur between March and August, the season when the ticks are most active. The incidence of fly transmitted infection is the greatest from June to September, during which time *Chrysops discalis* is most prevalent.

The prevalence of tularemia is the greatest in rural districts where the inhabitants are exposed to infection by ticks and flies and through handling wild rabbits. The incidence of the disease is also relatively high among persons who work in markets or as cooks and who dress rabbits, or handle the dressed carcasses.

Many cases also occur among hunters who handle recently killed infected rabbits.

Transmission. Animals, and the insects infected by biting animals, are the sole sources from which the infection is transmitted to man. While, theoretically, the infection could be transmitted from person to person by contact, actually, transmission by contact between persons is extremely rare.

In most instances, transmission is effected by the inoculation of the body fluids of infected animals through abrasions of the skin, through the unbroken skin, or into the conjunctival sac. Usually, the infection is transferred during the process of dressing or otherwise handling the carcasses of infected animals. In other instances, infection is produced by the bite of an infected tick or fly. Occasionally, man acquires the disease by the ingestion of insufficiently cooked flesh of infected rabbits.

The infection is transmitted among animals by blood sucking insects—ticks, lice, flies and fleas.

Chrysops discalis remains infectious for not more than a few days, and transmission of the infection is purely mechanical by means of contaminated mouth parts.

The tick, *D. andersoni,* remains infected for life and constitutes a permanent insect reservoir of infection. The bacilli are transmitted through the egg stage to the next generation.

Control measures. From a practical viewpoint, control of tularemia consists chiefly of measures which will prevent the transmission of the infection from the carcasses of rabbits to man. As the liver and spleen are usually removed during the dressing process, it is difficult to detect infection by market inspection of rabbit carcasses. Those whose vocation requires them to dress rabbits or to handle the dressed carcasses should wear rubber gloves while at work.

Past. tularensis is destroyed by exposure to a temperature of 135°F. for ten minutes. Consequently, ordinary cooking renders the infected meat safe. Freezing or refrigeration for as long as two years will not destroy the infection in rabbit carcasses.

The tularemia patient may be regarded as non-infectious to the extent that no isolation or quarantine is required. Hospital attendants should, however, exercise due care to avoid contact with any of the body fluids of the patient, such as dis-

charges from the ulcer, blood or serum. The organisms are easily destroyed by any of the common disinfectants.

As it is possible for any blood sucking insect to transmit the infection mechanically, measures should be taken to prevent access to the patient by bedbugs, fleas or lice.

TICK PARALYSIS

Tick paralysis is an acute disease characterized by malaise, irritability, anorexia, and progressive, ascending motor paralysis. The patient is usually afebrile, but fever may be present with symptoms of toxemia. Death is due to paralysis of the respiratory centers. The symptoms of tick paralysis are similar in many respects to those of poliomyelitis.

Tick paralysis is caused by the attachment and prolonged feeding of certain species of ticks. The tick is usually attached over the spine or to the scalp, especially the latter. Occasionally, the ticks are found attached in the axilla or groin.

Tick paralysis affects both man and animals. It occurs most frequently in children, although a few cases in adults have been reported. Among animals, it usually affects sheep and dogs. In the United States, the disease has been reported from Oregon, Montana, Wyoming, Idaho and Washington. It also occurs in British Columbia, Africa and Australia.

The cases of tick paralysis reported as occurring in the United States have been caused by the wood tick, *Dermacentor andersoni* and by *Ixodes ricinus californicus*. Elsewhere, other species of *Ixodes* have been involved.

Usually, the symptoms appear after the tick has been attached for from five or six days to two weeks. Prompt recovery follows the removal of the tick, if this is done before the onset of respiratory paralysis. Care must be taken to remove the mouth parts and head of the tick. Removal of the tick is facilitated by the application of a few drops of chloroform, ether or kerosene around the head of the tick.

Tick paralysis can be prevented by searching for and removing all ticks from the body after exposure to a tick infested environment. Tick control is discussed on page 984.

OTHER INSECT-BORNE DISEASES
(*Filariasis, Pappataci fever*)

A number of insect-borne diseases, other than those which have already been considered, occur in different parts of the world but, because of their geographical and local distribution and the epidemiological factors which govern the dissemination of the etiological agents, they do not occur, or occur but rarely, among United States troops. Among these diseases are filariasis, pappataci fever, leishmaniasis, trypanosomiasis and tsutsugamushi.

Filariasis. Filariasis is due to the presence in the lymphatics, connective tissues and mesentery of adult nematode worms belonging to the family Filariidae. Man is the definitive host and the larval forms, *microfilaria,* are present in the blood. Various species of mosquitoes, principally *Culex fatigans* and *Aedes variegatus,* serve as intermediate hosts for *Wuchereria bancrofti.* A number of other species, including species of Anopheles, have been incriminated as vectors of *W. bancrofti.* Biting flies belonging to the genus *Chrysops* (*Chrysops dimidiatus* and *C. silacea*) are the intermediate hosts of *Loa loa.*

Filariasis due to Wuchereria bancrofti. Infection with *W. bancrofti* produces no clinical symptoms in the majority of infected individuals. When present, the clinical manifestations in a typical case consist of lymphangitis with characteristic symptoms which may occur at more or less frequent intervals, chyluria, varices of the lymphatic vessels, especially of the scrotum and legs, and elephantiasis.

Geographically, filariasis due to *W. bancrofti* is widespread throughout the tropical and subtropical regions generally. It occurs in the West Indies, Central and South America, Central and West Africa, India, China, Australia and the Pacific Islands, including the Philippine Islands. It is especially prevalent in Samoa and the Fiji Islands. In the United States, indigenous cases have occurred in the vicinity of Charleston, South Carolina.

The control of filariasis consists entirely of the control of the transmitting insect host which, in the case of filariasis caused by *W. bancrofti,* is the mosquito (*supra*) (Chapter XXI).

Pappataci fever (*Sand fly fever, Phlebotomus fever*). Pappataci fever is an acute infectious disease characterized by sudden onset, fever of about three days duration, headache and pain

in the orbital regions, backache, congestion of the face, injection of the conjunctivae, anorexia and mental depression and physical prostration. It is non-fatal. The incubation period is from three to seven days.

Clinically, pappataci fever bears a marked resemblance to, and may be easily confused with dengue, except that there is no eruption and the secondary rise in fever does not occur (page 855).

Pappataci fever is due to a filterable virus, which apparently is present in the peripheral blood only during the first day of the disease. The infection is transmitted from person to person by species of the genus *Phlebotomus* (*sand fly, moth midge*), principally by *Phlebotomus papatasii.* A period of six or seven days elapses after the insect has bitten a pappataci fever patient before it can transmit the infection to another person. One attack of the disease confers a certain degree of immunity, which is not, however, permanent in all cases. Second attacks are common, but are usually milder than first attacks.

The control of pappataci fever is based primarily on the control of *Phlebotomus* (page 990). Precautions should be taken to prevent the infection of *Phlebotomus* by preventing them from gaining access to the patient during the first day of the disease.

CHAPTER XXI.

MOSQUITO CONTROL

Mosquitoes are of importance to the health of man either as transmitting agents of disease producing parasites, or as pests which are sources of discomfort. Mosquito control measures are therefore employed either to prevent the transmission or to reduce the incidence of mosquito-borne diseases, or to prevent discomfort due to bites of the insects.

From a health viewpoint the control of the disease bearing mosquitoes is by far the most important objective of mosquito control. The mosquito genera which are known to transmit disease to man are as follows:

Mosquito genera	*Disease transmitted*
Anopheles	Malaria
Aedes	Dengue
	Yellow fever
	Filariasis
Culex	Filariasis

Not all species of the disease bearing genera are capable of transmitting disease to man, nor are all those species which can convey infection of equal importance as actual vectors of disease. The habits and characteristics of a species will frequently determine the extent of its contact with man and, therefore, its opportunity for acquiring or transmitting infection. Also, there is apparently considerable variation in the inherent ability of different species to become parasitized when exposed to infection under natural conditions. Consequently, certain species, though they are capable of serving as hosts for the infecting organisms,

are, nevertheless, weak or inefficient vectors of the disease in question. Other species under like circumstances, because of their intimate contact with man or the facility with which they become infected, are efficient and dangerous transmission agencies.

RESPONSIBILITY FOR MOSQUITO CONTROL

As the control of mosquitoes is an important factor in protecting the health of the troops, the Medical Department is responsible for investigating and reporting upon conditions which render the control of mosquitoes desirable or necessary, and for making recommendations relative to control measures. The Quartermaster Corps is responsible for procurement and supply of the equipment, material and labor required. Normally, the Quartermaster Corps is also responsible for the execution of control measures, but in many instances, because of the technical nature of such procedures, the Medical Department exercises direct and immediate supervision over all anti-mosquito work. The commanders of subordinate units are responsible for the execution of control measures where such procedures are organizational activities.

CLASSIFICATION OF MOSQUITOES

Mosquitoes belong to class Insecta, order Diptera, suborder Orthorrapha, section Nematocera and family Culicidae. The family *Culicidae* contains subfamily *Chaoborinae*, subfamily *Culicinae* and subfamily *Dixinae*.

The subfamily *Culicinae* are the true mosquitoes and are grouped into three tribes. These are tribe *Anophelini*, tribe *Culicini* and tribe *Megarhinini*. Tribe *Anophelini* consists of genus *Chagasia*, genus *Bironella* and genus *Anopheles*. Tribe *Culicini* is composed of five groups which are group *Sabethes*, group *Uranotaenia*, group *Theobaldia*, group *Aedes* and group *Culex*. Tribe *Megarhinini* contains only the genus *Megarhinus*. Only certain species of genus *Anopheles*, group *Aedes* and group *Culex* are concerned in the transmission of disease to man.

The important species of the *Culex* group are *Culex fatigans*, a transmitter of *Filaria bancrofti*, and *C. pipiens*, which closely resembles *C. fatigans* in its characteristics and habits.

The *Aedes* group contains a number of species, the more important of which are *Aedes egypti* (*Stegomyia fasciata*), *Aedes albopictus* (*Aedes scutellaris*) and *Aedes variegatus*. *Aedes egypti* transmits yellow fever and dengue. *Aedes albopictus* is the transmitter of dengue in the Philippine Islands. *Aedes variegatus* transmits *Filaria bancrofti*. *Aedes vexans* (*the common wood mosquito*), *Aedes sollicitans* and *Aedes taeniorhynchus* (*the salt marsh mosquitoes*) frequently cause a great deal of discomfort, but are not known to convey any disease to man. The latter is a common pest mosquito in Panama.

The genus *Anopheles* consists of a large number of species some of which are transmitters of the malaria parasite (page 842).

LIFE CYCLE AND CHARACTERISTICS

Mosquitoes develop by complete metamorphosis and the life cycle consists of egg, larval, pupal and adult stages. The egg, larval and pupal stages are passed in water while the adult is a free flying insect.

The egg stage (Fig. No. 273). Mosquito ova are dark, oval bodies varying in size from 0.5 to 2 mm. in length. They are deposited either singly or in masses on the surface of water or near the edge of water collections. In a favorable environment, the eggs of all mosquito genera hatch in from 12 to 72 hours. Under adverse conditions the egg stage of Aedes may be greatly prolonged.

The eggs of Anopheles are deposited singly on the surface of water, usually in batches of from 40 to 100 or more. Anopheles ova are from 0.5 to 0.8 mm. in length. They are boatshaped with a membranous ribbed structure or float on either side. If undisturbed, Anopheles eggs tend to collect together into triangular, star shaped or ribbon-like groups or patterns (Fig. No. 274).

The eggs of *Aedes egypti* are usually deposited on the surface or near the edge of water contained in artificial receptacles located in or near inhabited buildings. Natural collections of water which are near occupied houses may be utilized as breeding places. The eggs may be deposited on the sides of the container or on the earth above the level of the water. They are laid singly, usually in lots of 25 to 50 or more. Those laid on the

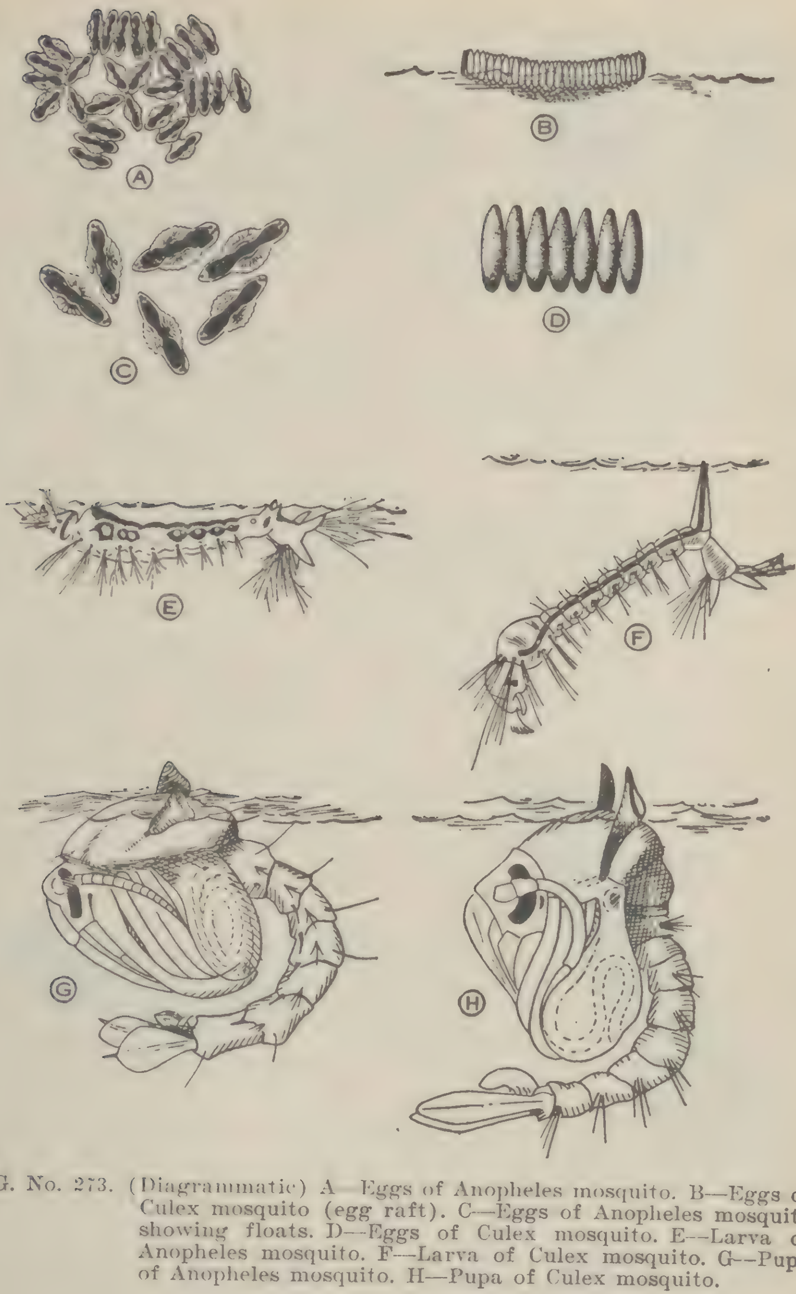
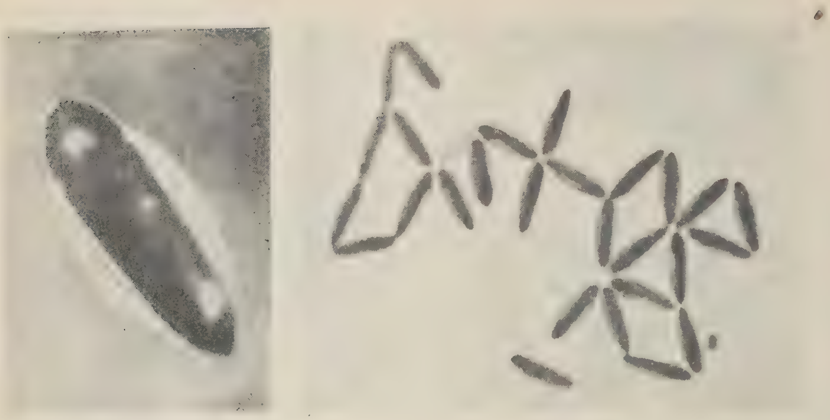


FIG. No. 273. (Diagrammatic) A—Eggs of Anopheles mosquito. B—Eggs of Culex mosquito (egg raft). C—Eggs of Anopheles mosquito showing floats. D—Eggs of Culex mosquito. E—Larva of Anopheles mosquito. F—Larva of Culex mosquito. G—Pupa of Anopheles mosquito. H—Pupa of Culex mosquito.



A. B.

FIG. No. 274. A—Egg of Anopheles mosquito showing floats. (Photograph). B—Typical arrangement of Anopheles eggs in geometrical patterns in water. (Photograph). (Courtesy of Lieut. Colonel James P. Crawford, Medical Corps, United States Army, Chief, Division of Entomology, Army Medical School, Washington, D. C.)

A. B.

FIG. No. 275. A—Egg of a Culex mosquito. (Photograph). B—Typical raft of Culex eggs in water. (Photograph). (Courtesy of Lieut. Colonel James P. Crawford, Medical Corps, United States Army, Chief, Division of Entomology, Army Medical School, Washington, D. C.)

surface of the water may sink to the bottom without interference with hatching. In an unfavorable environment, the eggs of *Aedes egypti* may lie dormant for months without losing their vitality. They are resistant to drying and cold and will hatch if placed in water after several months storage in dry or cold places (Fig. No. 276).

The eggs of Culex are deposited in raft or boat shaped masses from four to eight mm. in length, consisting of from 100 to 400 eggs cemented together (Fig. No. 275).

The larval stage (Fig. No. 277). Mosquito larvae are actively motile, cylindrical organisms. They vary in length from 1 mm. to about 10 mm., depending on the genus and species and the stage of development. They may be gray, green, yellowish or reddish brown, dark brown, or black in color.

Development. The mosquito larva develops by moulting, that is, the skin splits and a larger and more fully developed form emerges. The larva moults four times and at the fourth moulting passes into the next, or pupal stage.

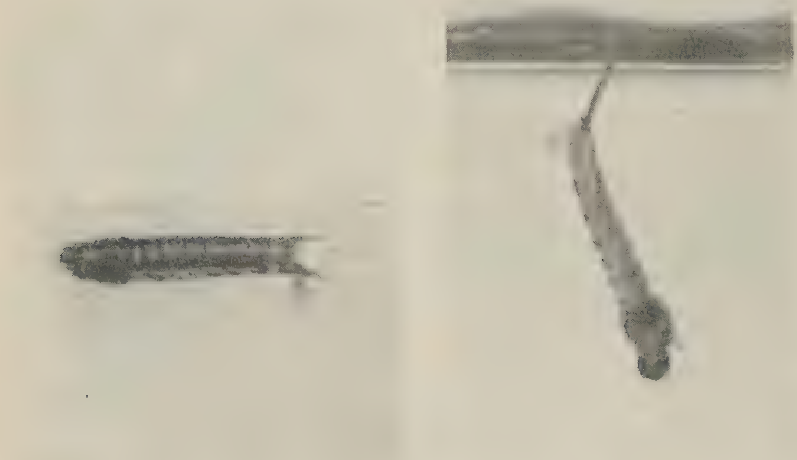
Given a relatively high atmospheric temperature, ample food supply and other favorable conditions as to sun and shade, the larval period of development may be completed in as short a time as five days. In a more adverse environment, especially if the temperature is low, development is inhibited and the larval stage may be prolonged for several weeks. Under average conditions in the tropics, or during the warm seasons of the year in the temperate zones, the larval period is usually completed in about ten days.

The larval phase of development is divided into four stages or instars. Under certain conditions, the stage of larval development may be an important factor in estimating the efficacy of larvacidal control and determining the frequency with which larvacides should be applied.

The first stage, or first instar, larva is the form that emerges from the egg. It is a minute, nearly transparent body. First stage larvae develop rapidly and reach the first moult in about 24 hours, when they pass into the second stage, or second instar. The second stage larvae are darker, larger and more easily detected in the water. In the second stage, the specific anatomical characteristics are more fully developed than in the preceding stage. After a period of growth the second stage larvae

A. B.

FIG. No. 276. A—Egg of *Aedes egypti*. (Photograph). B—Typical arrangement of eggs of *Aedes egypti* in water. (Photograph). (Courtesy of Lieut. Colonel James P. Crawford, Medical Corps, United States Army, Chief, Division of Entomology, Army Medical School, Washington, D. C.)



A. B.

FIG. No. 277. A—Larva of Anopheles mosquito showing typical horizontal position in water. (Photograph). B—Culex larva in typical position in water. (Photograph). (Courtesy of Lieut. Colonel James P. Crawford, Medical Corps, United States Army, Chief, Division of Entomology, Army Medical School, Washington, D. C.)

moult and enter the third stage. During the third stage, feeding and growth continue until moulting occurs, when the fourth stage forms emerge. Fourth stage larvae are mature and practically full grown. The head is broad and prominent. After a period of feeding the fourth stage larva becomes quiescent and soon thereafter the skin splits to permit the pupa to escape.

Respiration. All mosquito larvae possess breathing apparatus which enables them to obtain oxygen from the air. Contact with the air is made by means of a siphon tube or a stigmatic opening on the eighth abdominal segment. All genera except Anopheles have a distinct siphon tube. Anopheles larvae have, in lieu of a siphon tube, a stigmatic opening through which air is obtained. The siphon tube of the Culex is long and slender while that of the Aedes is shorter and somewhat barrel shaped.

Resting position. Most of the mosquito larvae which possess siphon tubes attach themselves by the tip of the siphon to the surface film of the water and hang head downward at an angle from the surface. This is always true of Culex and Aedes larvae. In this position they can obtain air from the atmosphere and food from the water. The exceptions are certain species of Uranotaenia and Mansonia. The former, though they have a short siphon tube, lie parallel to the surface of the water and may, because of the horizontal position they assume, be mistaken on superficial observation for Anopheles larvae. Some of the Mansonia species have a pointed and hooked siphon tube by which they attach themselves to the roots or stems of aquatic plants, below the surface of the water, and obtain oxygen through the tissues of the plant.

As the Anopheles larva has no siphon tube, it assumes a horizontal position at the surface of water in order to obtain air through the flat stigmatic opening which replaces the siphon tube of other genera.

Method of feeding. Mosquito larvae, generally, subsist on minute particles of vegetable matter and microscopic organisms. A few are carnivorous and predatory and consume other larvae. The mouth parts are equipped with mouth brushes which by vibration create currents that carry floating particles into the mouth.

Because of their horizontal resting position at the surface of the water Anopheles larvae feed on material floating in or just below the surface film.

Locomotion. Mosquito larvae move tail foremost through the water by relatively rapid darting or jerking movements. Anopheles larvae usually wriggle along parallel to the surface of water but may, when frightened, dive vertically to some depth. The larvae of other genera tend to swim at greater depths. The larvae of certain genera, such as Aedes, may remain submerged for some time and hide in the mud or debris at the bottom of the breeding water.

The pupal stage. A mosquito pupa is a comma shaped body enclosing the developing adult within a pupal case. The head and thorax of the insect form a globular mass called the cephalo-thorax, to which is attached the curved flexible abdomen. Two paddle shaped appendages are attached to the extremity of the abdomen and two breathing tubes, or trumpets, arise from the dorsum of the cephalo-thorax.

The pupae obtain air through their breathing trumpets. They are actively motile, locomotion being accomplished by flexion and extension of the abdomen. They have no mouth parts.

The pupal stage varies somewhat in length, but usually lasts from 24 to 72 hours. At the end of that period the pupal case splits and the full grown insect gradually emerges. As soon as the wing veins and the exoskeleton have hardened in the air the mosquito is ready for flight.

The adult stage. With few exceptions the female mosquito is a blood-sucking insect. It is probable that blood is required to stimulate the mating instinct and for the development and maturation of the ova. The males have no piercing mouth parts and subsist entirely on plant juices and exudates.

The adult mosquito in its relation to man may be classified as domestic, semi-wild and wild. These characteristics vary not only with the genus but also with species within the genus, and the habits of a genus or a species in this respect exert an important influence on its efficiency as a transmitter of disease and on the nature and efficacy of control measures. *Aedes egypti* is an example of the domesticated type and prefers breeding and resting places in, or in the vicinity of, human habitations. Anopheles are semi-wild and those species which frequent inhabited buildings do so naturally only in search of blood. Otherwise, they spend their resting periods and prefer breeding

places away from human habitations. The degree of shyness or wildness of Anopheles also varies with the species.

The Culex mosquito (*C. fatigans* and *C. pipiens*) normally seeks breeding and resting places outside of inhabited buildings but, being essentially domestic, it will enter buildings freely in search of blood and utilize breeding places within buildings.

Some mosquitoes will bite only at night or during twilight, while others are active only during the daylight hours. The reaction to light is usually a generic characteristic. While the habits of a genus may be modified by hunger, most genera are normally crepuscular, diurnal or nocturnal in their biting activities. Thus, Anopheles are crepuscular and bite most freely at dusk or dawn, but some species bite freely during the night. They seldom bite in bright sunlight, but may occasionally bite in shady places during the day, or during cloudy days. Aedes are diurnal and bite by choice during the daytime, but will bite at night, especially in artificial light. Culex are normally nocturnal and are most active during the night, but will also bite freely during twilight and in the shade during the day, especially in the vicinity of their breeding places.

As blood is a factor in the reproduction process, the female mosquito is impelled in her search for blood by an instinctive craving, rather than by hunger alone. Mosquitoes, generally, prefer the blood of warm blooded animals. Some species will bite any warm blooded animal, while others, particularly *Aedes egypti*, prefer the blood of man. *Anopheles quadrimaculatus* seems to prefer human blood, while *A. punctipennis* and *A. crucians* apparently prefer to attack animals instead of man. Mosquitoes are probably attracted to a source of blood, either animal or man, by both sight and smell.

Species vary in their inclination to enter houses. *Aedes egypti* habitually feed and breed inside of inhabited buildings, while some of the other species of the genus Aedes seldom, if ever, enter buildings. *Culex fatigans* and *C. pipiens* are domesticated and enter buildings freely in search of blood. Of the Anopheles species in the United States, *A. quadrimaculatus* exhibits the greatest inclination to penetrate into the interior of houses. While *A. punctipennis* and *A. crucians* will enter houses to obtain blood meals, they prefer to bite out of doors and are essentially porch biters.

Temperature and humidity influence the biting activities of mosquitoes to the extent that, as a rule, all mosquitoes are much more active in warm, humid weather. In the case of Anopheles, activity is much decreased and biting ceases when the temperature of the air is less than 60°F. The optimum temperature is about 85°F. The optimum relative humidity is 85 per cent or more.

Resting places. Mosquitoes hide in secluded places during the time when they are not active in search of food. Thus, during the daylight hours Anopheles hide and rest under buildings, in the shade of vegetation, or if unable to escape from buildings, in dark corners or on dark walls, under shelves, in crevices, or behind hanging objects. *Aedes egypti* usually spend the hours of darkness resting in out of the way places within or near inhabited buildings. Culex mosquitoes avoid bright light during the daytime and hide or rest in shaded areas or darkened places.

Flight. Mosquitoes will migrate or disperse for varying distances from the place of emergence from the pupae. Lacking a nearby source of blood, Anopheles may fly as far as one mile or more and much longer flights have been reported. It is probable that they will normally fly freely to a distance of one-half mile to one mile from the breeding place, if blood cannot be obtained within a shorter distance.

Aedes egypti seldom fly for any great distance from the place of emergence. They may, however, be carried for long distances on trains, ships or other conveyances.

Hibernation. Mosquitoes pass through the winter months, or from one breeding season to another, in either the adult, larval or egg stage.

In the temperate zone, Culex and Anopheles are, as a rule, maintained during the winter season by hibernation of gravid females. When the temperature falls during the autumn season, the males die and the fertilized females seek a sheltered place where they remain in a dormant or semi-dormant state until the beginning of the next breeding season. When climatic conditions again become favorable for the development of the immature forms, hibernation ceases, one batch of ova is deposited, and the adult dies. In the case of a few species of Anopheles, it is thought that hibernation may normally occur in the larval stage.

Aedes egypti pass through the period between breeding seasons in the egg form. With the approach of the winter season, the adults die and the eggs which have been deposited in breeding places remain dormant for months or until environmental conditions, with regard to moisture and temperature, permit further development.

In cold climates where adults cannot obtain protection, it is probable that all species pass the winter months in the egg stage. In tropical and semi-tropical regions and in the warmer sections of the temperate zone, maintenance of the species through a period unfavorable for normal development may be accomplished by retarded development instead of true hibernation. Under these conditions, the adults feed and oviposition takes place, but development of the immature forms is slow and inhibited, with a marked increase in the length of the various stages, especially the larval stage. In the United States, Anopheles apparently do not normally pass through a stage of true hibernation south of latitude 32° N.

Longevity. Under favorable conditions it is probable that the adult female mosquito may live as long as three months. They are, however, subject to many dangers from natural enemies and from adverse climatic and other environmental conditions. Because of these factors the normal life expectancy of the mosquito is probably two weeks to one month, and, when breeding places are controlled, the majority of the adult forms present in a locality may be expected to disappear within a month.

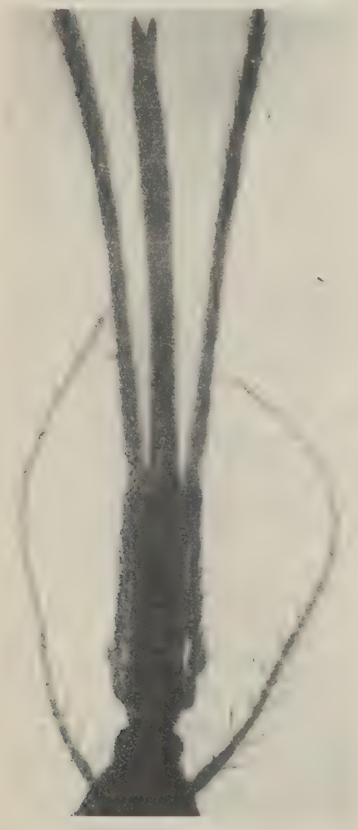
IDENTIFICATION OF MOSQUITOES

Mosquitoes (subfamily Culicinae) are differentiated, with a few exceptions, from all other diptera by the presence of scales on the head and wings and by a proboscis which is as long or longer than the head and thorax combined.

Ability to differentiate the genera and, to a certain extent, the species of indigenous mosquitoes is essential in the intelligent application of mosquito control measures. This knowledge is necessary in determining the location of breeding places and in estimating the value or controlling the application of anti-mosquito procedures. Otherwise, much money, time and labor may be expended in the control of mos-

quitoes which are not actually or potentially concerned in the transmission of disease.

Usually, only a few different species are to be found in any given locality. Where this is the case the adults can, as a rule, be differentiated on careful inspection by easily recognized characteristic markings or anatomical features. The larvae can, in most instances, be differentiated generically by gross structural features. The identification of species by examination of the larvae requires considerable skill in making



A.

B.

FIG. No. 278. A—Mouth parts of female Anopheles mosquito, showing position and length of palpi. (Photograph). B—Mouth parts of male Anopheles mosquito. (Photograph). (Courtesy of Lieut. Colonel James P. Crawford, Medical Corps, United States Army, Chief, Division of Entomology, Army Medical School, Washington, D. C.)

entomological studies. If necessary, identification keys, such as those published in works on entomology, may be followed in making species identification of adults and larvae.

Differentiation of sexes. In the case of nearly all genera, the sexes can be readily differentiated by the type of antennae. The antennae of the male are plumose, having whorls or tufts of long silky hairs, while the antennae of the female have only short hairs (Figures No. 278 and 280).

Identification of larvae in the field. In the field, Anopheles, Aedes, and Culex larvae can be differentiated for practical purposes by the resting position they assume in the water, and by the presence or absence of a siphon tube, or by differences in the shape of the siphon tube. Other structural characteristics can be and are employed as a means of identification where more complete and accurate examinations with magnification are made.

Anopheles. Anopheles larvae are distinguished from Culicini larvae by their resting position parallel to and at the surface of the water, and by the presence of a stigmatic opening instead of a siphon tube on the eighth abdominal segment.

Aedes. Aedes larvae may be differentiated from Culex larvae by their relatively short, conical siphon tube. When resting they hang downward at an angle from the surface of the water.

Culex. Culex larvae hang downward from the surface of the water when resting, but are distinguished from Aedes by their elongated and relatively slender siphon tube.

Pupae. Differentiation of genera by simple field inspection of the pupae is difficult but may be accomplished by examination of the breathing trumpets or tubes. The breathing tubes of the Anopheles pupae are short, broad and funnel shaped. They arise from about the middle of the cephalothorax and are split in front. The breathing tubes of the Aedes pupae are short and broad but the opening is triangular in shape and there is no split. The Culex pupae possess long and slender breathing tubes which show no split and are attached to the posterior portion of the cephalo-thorax.

Identification of adults in the field. Adult Anopheles, Aedes and Culex can be distinguished one from the other by

differences in structure, markings and posture as determined by inspection.

As the different species of a genus frequently vary greatly in their ability or tendency to transmit disease to man, species identification may be an essential factor in the practical prosecution of control work. At times two or more species are present in a locality, one or more of which are known to be vectors of disease producing organisms, while the others are only weak or infrequent hosts. Under such circumstances, it may be desirable to concentrate on the control of the more

A. B.

FIG. No. 279. A—Photograph of Anopheles mosquito in act of biting finger. This is the typical biting and resting position of the Anopheles mosquito. B—Photograph of *Aedes egypti* in act of biting finger. This is the typical biting and resting position of Aedes and Culex mosquitoes. (Courtesy of Lieut. Colonel James P. Crawford, Medical Corps, United States Army, Chief, Division of Entomology, Army Medical School, Washington, D. C.)

dangerous species, especially in the control of specific breeding places, and, in order to do so, species identification is necessary.

Anopheles. The genus Anopheles can be distinguished, generally, from other genera by the palpi of the female which are as long, or nearly as long, as the proboscis, by the presence of dark spots on the wings, and by the resting position. When at rest, the Anopheles mosquito, with a few exceptions, assumes a posture in which the body projects at an acute angle from the


A.


B.

FIG. No. 280. A—Mouth parts of female Culex mosquito. (Photograph). B—Mouth parts of male Culex mosquito. (Photograph). (Courtesy of Lieut. Colonel James P. Crawford, Medical Corps, United States Army, Chief, Division of Entomology, Army Medical School, Washington, D. C.)

resting surface, due to the thorax and abdomen being held in a straight line with the head and proboscis (Fig. No. 279). The angle thus formed varies somewhat in different species but is sufficient to constitute a generic characteristic, except for those few species which assume a culicine posture. In other genera, the palpi of the female are much shorter than the proboscis, the wings are usually without spots, and in the resting position the body is approximately parallel to the resting surface, the abdomen being held at an angle to the head and thorax. The principal and most dependable generic characteristics of Anopheles are the long palpi of the female and the posture. For practical purposes these are sufficient to identify the genus (Figures No. 278 and 279).

The species of adult mosquitoes are differentiated by differences in the male genitalia and by variations in the distribution of colored scales on the wings, palpi, legs and body. Where distinct and easily seen variations in markings are present, differentiation of species by inspection in the field is practicable. For

FIG. No. 281. Female *Anopheles quadrimaculatus.* (Photograph). (Courtesy of Lieut. Colonel James P. Crawford, Medical Corps, United States Army, Chief, Division of Entomology, Army Medical School, Washington, D. C.)

example, in the United States the more common and more widely distributed species of Anopheles are *A. quadrimaculatus, A. punctipennis* and *A. crucians* and may be differentiated as follows:

> *A. quadrimaculatus* is distinguished by four, sometimes three or five, dark spots on the wings and its uniformly dark color. *A. punctipennis* may be differentiated from either of the other two species by the presence of an oblong white spot on the outer third of the anterior border of the wing and a small white spot near the tip of the wing. *A. crucians* has three dark spots on the sixth wing vein and white bands on the palpi of the female.
>
> *A. maculipennis,* which is found in the western part of the United States, closely resembles *A. quadrimaculatus.* It may be distinguished from *A. quadrimaculatus* by differ-

ences in the male genitalia and possibly by a coppery spot or reflection in the fringe of scales at the tip of the wing. It cannot, however, be readily differentiated from A. *quadrimaculatus* by inspection in the field.

A. *pseudopunctipennis* presents three white spots on the anterior margin of the wing. The palpi have white tips and white bands which serve to distinguish it from A. *punctipennis* with which it may be easily confused on superficial examination.

Aedes. (*A. egypti, A. albopictus, A. variegatus*). Aedes, generally, are small black or dark brown mosquitoes having a number of white or silvery markings. *Aedes egypti* because of

FIG. No. 282. Female *Anopheles albimanus.* (Photograph). (Courtesy of Lieut. Colonel James P. Crawford, Medical Corps, United States Army, Chief, Division of Entomology, Army Medical School, Washington, D. C.)

FIG. No. 283. Female *Aedes egypti*. (Photograph). (Courtesy of Lieut. Colonel James P. Crawford, Medical Corps, United States Army, Chief, Division of Entomology, Army Medical School, Washington, D. C.)

its wide distribution and ability to transmit dengue and yellow fever, is the most important species of the genus Aedes. It is distinguished by two median straight and two lateral curved silvery white lines on the dorsum of the thorax which form a lyre-shaped design. *A. albopictus* (*A. scutellaris*) presents a single, silvery white line extending down the middle of the dorsum of the thorax. *A. variegatus* differs from *A. albopictus* only in the presence of white lines instead of spots on the pleurae. These characteristic markings serve to distinguish Aedes from

Culex. The palpi of the female Aedes are less than one-half as long as the proboscis, differing in this respect from Anopheles (Fig. No. 283).

Culex. The important species of the genus Culex (*C. fatigans* and *C. pipiens*) may be differentiated from Anopheles and Aedes by their uniformly brown color with yellowish ornamentation, the pale bands on the dorsal surface of the abdomen, and the short palpi of the female which are never one-half as long as the proboscis.

Identification of larvae. The identification of species by direct examination of the larvae is based on the position, number and shape of certain hairs and scales and is not therefore a practical method for use in the field, except by a trained entomologist.

Larvae may be differentiated by the identification of adults hatched from captured larvae and pupae. This method should be used only when facilities are not available for identification of larvae by direct examination.

Method of capturing larvae. The equipment required for capturing and collecting mosquito larvae consists of a dipper, a glass jar or other wide mouthed receptacle, and a spoon. The dipper may be the ordinary large drinking type with an inside coating of white enamel and a hollow handle from 12 to 18 inches long. The length of the handle can be increased as desired by inserting a stick into the hollow end. A white bottomed enamel ware saucer, which can be carried in the pocket, may be used in lieu of a dipper. If it is desired to preserve the captured larvae for hatching purposes, or for direct examination under a microscope, they are removed from the dipper with the spoon, or with a pipette, and placed in the glass jar together with sufficient water to prevent their injury during transport. If captured larvae are to be transported under conditions which will subject the container to much shaking, special care must be taken to prevent their injury or destruction. A bottle is filled with water and then emptied so as to leave a film of moisture on the sides and bottom. The larvae are then placed in the bottle and any surplus water which may have been placed in the bottle with the larvae is drained away. The bottle is then tightly sealed to prevent the evaporation of the film remaining on the sides and bottom.

Two methods of dipping may be used. The edge of the dipper may be passed below the surface of the water and the dipper turned so that it will take up the water at the point where the dip is made. This is usually the most successful method of dipping under all conditions. Or the edge of the dipper is passed below the surface of the water to a depth of from one to two inches and swept through the water for a distance of from two to three feet and then raised. With either method, skill and care must be exercised to prevent the larvae from escaping by diving or from being washed out of the dipper.

When frightened by shadows or disturbance of the water, mosquito larvae may dive and hide under or in vegetation or debris, and casual examination of the water by dipping may fail to reveal their presence. Sometimes the larvae hiding in vegetation may be captured by rapidly pushing the dipper up to the plant or grass stalks, when the larvae will be drawn out of their hiding places by the suction of the water as it enters the dipper. In small collections of water, hiding larvae may be detected by the addition of a small amount of cresol to the water which will cause them to rise to the surface. Anopheles larvae may at times be more easily found if the water is stirred with a stick until it is turbid, when the larvae will rise and can be readily seen at the surface of the muddy water.

As a rule, *Anopheles* larvae are found in small natural collections of water where protection is afforded by vegetation and debris. Search should be made in small ponds, puddles, and in the indentations and potholes along the edges of streams and ditches and the larger ponds or lakes. Anopheles larvae are not usually found where the protection and food provided by aquatic vegetation are absent. It must not be forgotten that in the absence of natural receptacles for water, certain species of Anopheles may breed in water in artificial containers.

Aedes egypti larvae are usually found in water contained in artificial receptacles from which they may be captured by dipping with a dipper, saucer or spoon. If frightened they tend to dive to the bottom of the receptacle and may remain there for a considerable length of time. If the water is emptied from small containers, the larvae may be found in the mud or silt remaining on the bottom.

Culex larvae are captured by dipping in the same manner as Anopheles larvae. They may be found in any kind of water and in locating their breeding places no collection of water, whether clear or dirty, natural or artificial, should be neglected.

Hatching of adults from captured larvae. The captured larvae and pupae are placed in water contained in pans, wide mouthed receptacles, saucers, or petri dishes which are in turn contained within a mosquito hatching cage or under a larger inverted glass vessel.

The breeding water should be that obtained from the breeding place of the captured specimens, so as to simulate natural conditions and provide a food supply. Food may also be furnished the larvae in the form of yeast, algae, or hay infusion. The hatching cage or other container should be placed away from bright light, and where there is no breeze or draft.

Larvae can be developed to adults under artificial conditions only by careful supervision. Despite all precautions and care, the mortality is usually high, especially among the first and second stage larvae. Nor can all species be developed with equal success, as certain of them possess but little resistance to the adverse factors imposed by the artificial conditions. Further, where mixed breeding occurs, the larval forms of one or more of the species present may not develop to the adult stage when removed from their natural habitat. Because of these difficulties, where practicable, only third and fourth stage larvae and pupae should be selected for hatching out purposes.

Mosquito hatching cage (Fig. No. 284). A hatching cage should be used if more than a few lots are to be developed. The cage has a wooden bottom and top, and the sides consist of wire screening. In the front of the cage is an opening to which a netting sleeve is attached. When adult insects have emerged, they may be captured with a catching tube passed through the sleeve.

A simpler method where only a few larvae are to be hatched, is to place the water containing the larvae in a small wide mouthed jar or a dish, over which is inverted a larger glass vessel. The latter should be large enough and so shaped that it will leave several inches of space above and around the smaller container (Fig. No. 285). A lantern globe placed over a petri dish and closed at the top with one or two layers

FIG. No. 284. Mosquito hatching cage used in the laboratories of the Army Medical School. (Courtesy of Lieut. Colonel James P. Crawford, Medical Corps, United States Army, Chief, Division of Entomology, Army Medical School, Washington, D. C.)

of gauze may also be used (Fig. No. 285). When the adults have hatched out, they fly to the top and sides of the larger container and can then be killed by inserting into the jar, or other container, a small piece of cotton saturated with chloroform.

Larvae may be hatched without using a mosquito cage by allowing the larvae to pupate in an open receptacle (*supra*) and

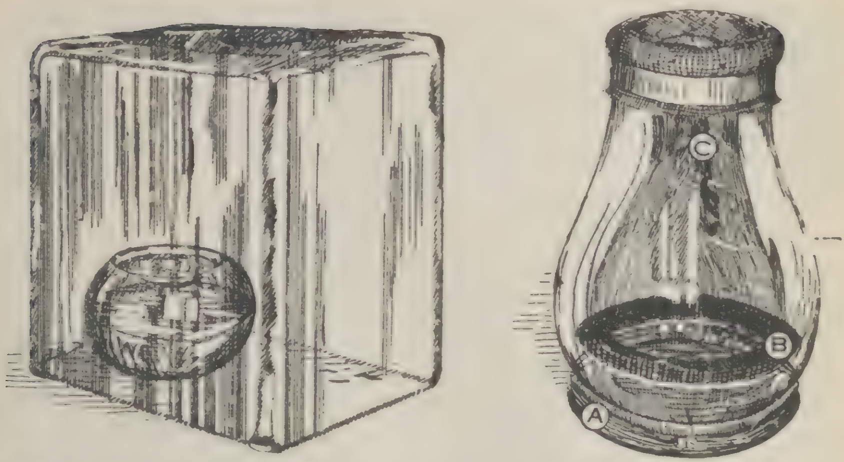


FIG. No. 285. Containers for hatching mosquitoes. Left, museum jar. Right, lantern globe over petri dish and covered with a gauze top secured by adhesive. A—Petri dish. B—Cardboard for insects to rest upon. C—Hanging cord to serve as resting place for the mosquitoes.

then transferring the pupae to a test tube containing a small quantity of water. The test tube should be lightly plugged with cotton.

The adults obtained by the development of captured larvae or pupae may be immediately identified, preserved for future study, or forwarded to an authorized laboratory for identification.

Shipment to laboratories. In preparing mosquitoes for shipment to distant laboratories for species identification, they must be so packed that they will not be broken nor the scales rubbed off in transit. The insects should be dry, as moistening renders them difficult to study. The bottom of a cardboard box, such as a pill or capsule box, is lined with glazed cotton and the dead insects carefully placed on the cotton in such a way that they do not become entangled with each other. If glazed cotton is not available, ordinary cotton may be used by placing lens paper between the cotton and the mosquitoes. The mosquitoes will be seriously damaged if allowed to come into contact with plain cotton. Not more than from five to ten mosquitoes should be placed in one box. The insects are then covered with glazed cotton so that they are separated from the sides of the box and from each other. The cotton should be

packed very lightly, using only sufficient pressure to hold the insects in place. In order to protect the mosquitoes from insects and moulds, two drops of commercial formalin or a small quantity of naphthalene should be placed in the lid, just before closing the box. The formalin must not come in contact with the mosquitoes. Preferably, the box should be mailed in a mailing tube to avoid damage during transit.

Larvae and pupae may be preserved and shipped in a ten per cent formalin solution containing 0.5 per cent of borax and 2 per cent of glycerin. The specimens are first killed by immersion in hot water and then transferred to the preservative. Only moderately hot water should be used for killing (140°F.), as boiling, or even very hot water, will cause distortion of the specimen. Larvae may also be preserved in 70 per cent ethyl alcohol to which a small quantity of glycerin has been added.

A statement should accompany each collection forwarded for identification, giving the station and the name of the collector. If the mosquitoes are captured adults, the date, hour, and a description of the locality where captured, such as, barracks, family quarters, tents, or stables, should be given. If they are hatched specimens, or larvae or pupae, the breeding places where the immature forms were captured should be described. In all cases, the accompanying statement should contain information relative to the occurrence of mosquito-borne diseases at the station concerned.

GEOGRAPHICAL DISTRIBUTION

Mosquitoes belonging to Anopheles, Aedes and Culex genera are to be found in nearly all parts of the world. In many instances, however, the species of these genera which are important in the transmission of disease have a limited distribution and are present only in certain areas.

Anopheles. The species of Anopheles capable of transmitting malaria are, in general, widely distributed throughout the tropical and temperate zones. However, the distribution of any of these species may be, and frequently is, restricted geographically to a limited area. The distribution of the more common species of Anopheles which are known or sus-

pected vectors of malaria in the United States and its foreign possessions is shown in the following table. No Anopheles have been reported from the Hawaiian Islands.

United States	**A. quadrimaculatus* **A. maculipennis* *A. punctipennis* *A. pseudopunctipennis* *A. crucians* *A. walkeri* *A. atropos* *A. barberi*
Panama	*A. albimanus* *A. tarsimaculatus* *A. argyritarsus* *A. pseudopunctipennis* *A. punctimacula*
Philippine Islands	*A. minimus* *A. maculatus*
Porto Rico	*A. albimanus* *A. grabhamii* *A. vestitipennis*

**A. quadrimaculatus* and *A. maculipennis* are the important malaria vectors in the United States. The other Anopheles found in the United States do not commonly transmit malaria either because they are too rare or are not readily infected.

In the United States, *A. quadrimaculatus* is found throughout the Southern and Southeastern states generally, and as far north as New York and Illinois. *A. maculipennis* is the malaria vector of the Far West and occurs in the Pacific Coast region from California to Alaska. It also occurs in Canada and along the northern border of the United States eastward to the Atlantic. It has been found in New Mexico. *A. crucians* occurs in the Atlantic Coast region and in the lower part of the Mississippi Valley. *A. punctipennis* is distributed generally throughout the United States except in the arid regions. *A. pseudopunctipennis* is found in the Southwestern States, principally California, Arizona, New Mexico and West Texas. *A. walkeri* is quite rare. It has been found in parts of New York, Florida, Mississippi and

Arkansas. *A. atropos* is also a rare species occurring along the Atlantic and Gulf coasts. *A. barberi* is another rare species found in the Southeastern States.

Aedes. *Aedes egypti* is to be found generally in the populated districts of the world between 38°N. and 38°S.

Aedes albopictus is common in the Orient, generally. *Aedes variegatus* prevails in the South Pacific Islands, especially the Fiji Islands.

Local distribution. The local distribution of genera, or of the different species, in any section or area depends on a number of factors, such as types of breeding places available, variations in climatic conditions, cultivation of the soil, or protection from sun and wind. In general, the local distribution of a genus or species of mosquito is determined by, and coincides with, the distribution of suitable uncontrolled breeding places.

In the Western Hemisphere the conditions which favor the breeding of Anopheles are usually found in low lying areas, swampy districts, along coastal plains, in delta sections and in the valleys of the larger rivers. The impounding of water for industrial or other projects may provide conditions suitable for the breeding of Anopheles where none existed before, or may serve to modify the prevalence of a species. In the Philippine Islands, *A. minimus* breeds in clear water streams in the foothills and low mountainous districts. It is not found where the elevation is more than 2000 feet, nor on low coastal plains.

BREEDING PLACES

Mosquito breeding places are collections of water in which the aquatic phase of the cycle occurs, that is, where the ova are deposited and the larvae and pupae develop. The location of the breeding places of disease transmitting species is an essential part of a mosquito survey and is necessary for the accomplishment of adequate mosquito control.

Most mosquito genera exhibit a preference for a certain type of breeding place. With some genera, this preference may be exhibited only as a matter of choice where the preferred type of breeding place is available and, if the preferred type is not available, they will breed freely in less desirable places. Other genera

or species will not breed, or will breed only in comparatively small numbers, if the preferred breeding places are not available.

In some instances, ova are deposited in a breeding place but development is incomplete and adult forms are not produced. An incomplete breeding place is indicated by the presence of young larvae and the continued absence of mature larvae and pupae and cast-off pupal skins. In an incomplete breeding place, the complete development of the immature forms is usually prevented by natural enemies, by substances in the water which kill the larvae, or by flooding which washes them away.

A potential mosquito breeding place may be revealed by the presence of larval and pupal skins, even though for the time being no immature forms are to be found.

Anopheles breeding places. Anopheles is not a domestic mosquito, in that it does not by choice breed in or near inhabited buildings. It commonly breeds in natural collections of fresh, clear water in ponds and pools, along the edges of moving water in ditches and streams, and in marshes and swamps. Each of the different species of Anopheles capable of transmitting the malaria plasmodium exhibits a preference for a certain type of breeding place, although in the case of some species this preference is only a matter of choice where the preferred type of breeding place is accessible. Some species will breed in brackish water when fresh water is not available, while others prefer brackish water to fresh water. A few of the species, in the absence of clear water, will breed in foul water. Other species, while preferring to breed in natural waters will, when such collections are not accessible, resort to the water contained in artificial receptacles in and about human habitations.

A. quadrimaculatus is a pond breeder, preferring quiet water, such as intermittent pooled streams, pools of rain water, small ponds, etc. It does not normally breed in streams or in acid waters.

A. maculipennis has much the same breeding preferences as *A. quadrimaculatus.* It is especially partial to small, shallow, sunlit pools or collections of water containing green algae.

A. punctipennis breeds in pools, in springs and often in small collections of rain water. It also breeds in and seems to prefer the quiet water along the edges of streams.

A. crucians, as a species, breeds in fresh or brackish water. There are two varieties, one breeding in fresh water and one in brackish water. The fresh water variety breeds in ponds, pools, fresh water swamps, barrow pits, etc., while the other variety breeds normally in salt water swamps and tidal pools.

A. pseudopunctipennis breeds by preference in clear water in pools, and in springs, along the edges of streams, in ditches and in puddles.

A. atropos breeds in brackish pools, and has been found in pools containing grass or algae.

A. walkeri seems to prefer to breed in water containing considerable vegetation, especially permanent waters. Its breeding places are not well known.

A. barberi breeds in water in tree holes.

A. albimanus will breed in fresh or brackish water in pools, ponds, swamps and along the edges of streams where there is no current. It will breed in small collections of water, sometimes where there is only a film of water present and the larvae may be found in the water in artificial containers. *A. albimanus* apparently prefers water that is exposed to the sun and contains algae.

A. tarsimaculatus prefers practically the same type of breeding places as *A. albimanus.*

A. argyritarsus prefers to breed in the small collections of fresh water in seepage pools, small ditches and hoofprints. It will also breed in the water in artificial containers.

A. punctimacula, as it occurs in Panama, breeds in shaded pools.

A. minimus breeds in clear water streams.

Aedes breeding places. *Aedes egypti* shows a strong preference for breeding in water contained in artificial receptacles in or near human habitations, such as barrels, cisterns, eaves troughs or gutters, unused plumbing fixtures, ornamental basins, or accidental collections of water. Only a very small quantity of water, which will remain for a week or 10 days, is required for the development of the immature forms into adults. *Aedes egypti* seldom breed away from human habitations, or in permanent waters such as swamps, marshes, streams, ditches or ponds. The breeding places of *Aedes albopictus* are similar to those of *Aedes egypti.*

Culex fatigans and *C. pipiens*, like *Aedes egypti*, will breed in water contained in artificial receptacles in or near inhabited houses but also prefer water containing organic material. They will breed freely in water contained in catch basins or cesspools and in swamps, roadside ditches or puddles.

SEASONAL VARIATIONS IN PREVALENCE

Many factors which are seasonal in origin influence and produce variations in the prevalence of mosquitoes. Rainy seasons and dry seasons, because of their effect on the extent and character of breeding places, are accompanied by increases or decreases in the number of mosquitoes. In the tropics some species are more numerous during the wet seasons and others during the dry seasons. For example, in Panama, *A. albimanus* is more prevalent during the rainy season and *A. pseudopunctipennis* during the dry season. Generally, in the temperate zone the number of mosquitoes rapidly decreases with a fall in temperature to below 60°F. A period of warm weather in the early spring or late winter may result in the appearance of early broods, with a consequent increase in prevalence during the following months.

Certain seasonal variations are characteristic of some species. *A. crucians* appears early in the spring in the southern part of the United States and may reach a maximum prevalence in March or April with a marked decrease in numbers during the summer months. *A. punctipennis* likewise appears early in the spring and tends to continue breeding until late in the fall. *A. quadrimaculatus* becomes numerous in the late spring or early summer. Its greatest prevalence is reached during the summer months with a rapid decrease during the late summer and early autumn.

CONTROL MEASURES

The habits and characteristics of mosquitoes are such that control measures may be designed to eliminate or control the breeding places, destroy the larvae, or control or destroy the adults. The measures which will be most effective in a given situation are determined by local factors and to some extent by the genus and species of mosquito concerned.

Anti-mosquito measures are directed against either the larval or adult forms and are either temporary or permanent in character. Permanent anti-mosquito measures are those designed to correct permanently or to remove conditions which make possible or facilitate the breeding of mosquitoes, or the continued existence of the adults. They include such procedures as drainage or filling of breeding places, the elimination or adequate care of artificial waters, or the removal of vegetation which provides protection for the adult. Temporary measures are effective only while they are being employed. They include the use of larvacides, catching of adult mosquitoes, and screening. Permanent, rather than temporary, anti-mosquito measures are always preferable where local conditions render them feasible and funds for their execution are available.

The anti-mosquito measures which are directed against the larval forms of the insect have for their objective either the elimination of the breeding places or the destruction of the larval forms in the breeding places. The elimination of the breeding places is accomplished by draining or filling areas which contain collections of water, by the elimination of indentations in the banks of streams and ponds, by the removal of flotage and vegetation from the water which cannot be drained away, and by emptying artificial water containers. The destruction of larval forms in a breeding place is usually effected by the application of oil or some poisonous compound to the water containing larvae. In other instances larvivorous fish may be employed.

The anti-mosquito measures employed against the adult mosquito have for their purpose the destruction of the mosquitoes or the protection of man from their bites. The destruction of the mosquitoes is accomplished by means of fumigation, swatting, hand catching, or the removal of vegetation which would protect the insects from the sun and wind. Man is protected from the bites of mosquitoes by the screening of buildings, by mosquito netting on beds, or by the use of head nets and gloves.

Drainage. Anti-mosquito drainage to be effective must usually be planned and installed for the specific purpose of eliminating or reducing the extent of mosquito breeding waters. Ordinary agricultural or roadside drainage not only frequently fails to remove the water in a way that will prevent mosquito breeding but, by spreading the water and increasing

its surface area, may actually cause an increase in mosquito breeding.

Anti-mosquito drainage may be accomplished by means of surface ditches of either the unlined, lined, or rock filled type, or by subsurface tile drains.

In planning a drainage system, consideration should be given to the probable period during which the ditches will contain water and to the best location of the ditches or tile lines with regard to grade and the type of soil. Careful planning for and supervision of the construction of a drainage system will increase its effectiveness and reduce the cost of maintenance.

In many instances, it will be found desirable to make a map or sketch of the area to be drained showing the location and available grade of at least the main ditches or subsurface drains.

Open ditches. In order to prevent mosquito breeding in the water in ditches, open ditches should be so constructed that standing water will be completely removed and storm water drained from the surface of the ground and from the ditches within a short time after a storm. The grade and width of the ditches should be such that while all water will be carried away, the velocity will not be sufficient to produce "potholes" by erosion of the bottom or sides of unlined ditches. Such potholes may contain water long after the remainder of the ditch is dry and may constitute prolific mosquito breeding places. A ditch that is too wide or too flat may likewise retain water in small depressions and thus defeat the purpose of drainage. Unless guarded against by frequent and careful inspection during construction, portions of the ditch will be excavated below or above the established grade, producing either low areas which will retain water when the rest of the ditch is dry or high sections which will prevent complete drainage.

Principal factors in ditch construction. Only a sufficient number of ditches should be dug to accomplish the desired purpose, that is, the removal of standing water or the prompt elimination of storm water. Too few ditches will fail to attain these objectives, while too many will increase the cost of construction and maintenance.

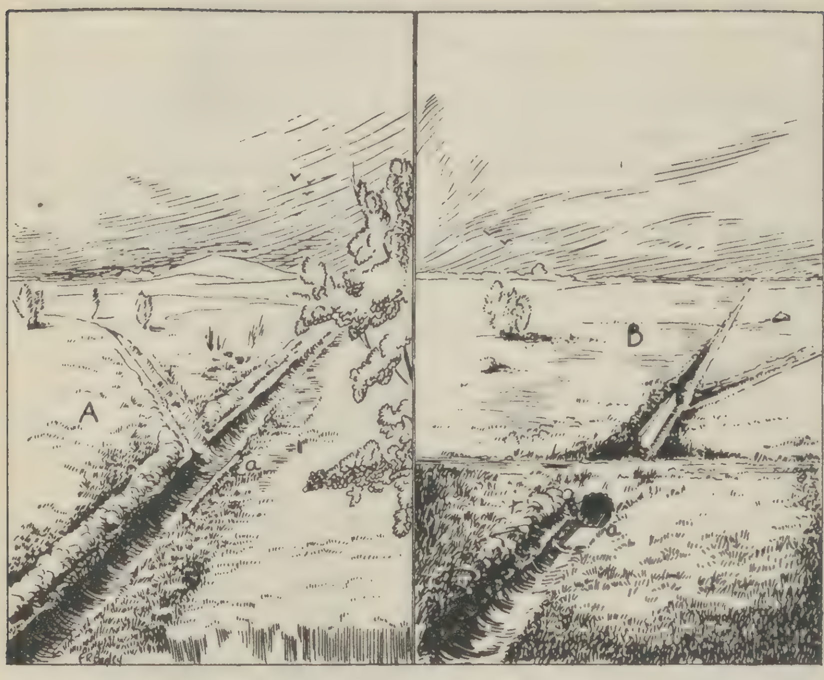


FIG. No. 286. Drainage ditches. A—Showing (a) splash board for ditch junction. B—Showing splash board at ditch junction and culvert under roadway, with concrete slab (a) at down stream end of culvert.

Generally, all ditches should be constructed with narrow bottoms, smooth sloping sides, with as few curves as possible, and without sharp turns. Usually, the sides of the ditches should have a slope of about 45 degrees, although in soft mud or sand the slope should be flatter, while in rock or clay the sides may be nearly perpendicular. If ditches are built at an angle to the slope of a hill, the upper side should be somewhat flatter than the lower in order to lessen erosion. The bottom of all ditches should be U-shaped, not V-shaped, and in the case of wide ditches, the bottom should slope towards the center even if the sides are vertical.

The main ditch should be constructed first and laterals installed only when and where they are necessary. At times, it may be expedient to wait until after a storm or heavy shower to determine the number and location of additional or lateral ditches.

A lateral or branch ditch should join the main ditch at an acute angle or gentle curve in order to avoid the deposition of debris or silt at the junction, or to prevent erosion of the opposite bank and the formation of holes in which water will be retained (Fig. No. 286).

Care should be exercised that the dirt thrown out in digging the ditch does not form spoil banks which, by preventing the drainage of surface water into the ditch, will create pools and puddles in which mosquitoes will breed. Where the ditch runs transversely to the slope of the ground, the excavated dirt should be placed on the downhill side. Where necessary, spoil banks should be leveled or the dirt disposed of elsewhere.

Where the ditch goes through a culvert or wherever a pipe section is installed, the grade should be increased to prevent interference with the flow by deposits of debris. At the downstream end of the pipe or culvert, the bottom of the ditch should be lined with stone or concrete for a distance sufficient to prevent erosion and the formation of a hole in the bottom of the ditch. The upper end of the pipe or culvert may, if necessary, be screened with iron rods or a wooden grating to prevent the entrance of large pieces of debris or flotage.

Use of dynamite. Dynamite may be used to an advantage in wet ground in the construction of large ditches of considerable length where there is sufficient fall and volume of flow to permit of irregularities in grade. This method is most suitable for ditching swamps and marshes where the soil is water soaked and where there are many surface and subsurface obstructions, such as brush and roots.

Dynamite cartridges are placed in holes made in the ground with an iron bar or a wooden pole. The size of the dynamite charge, and the spacing and depth of the holes depend upon the width and depth of the ditch and the nature of the ground, and are usually determined by trial shots. In the construction of the ordinary ditch the charges are placed about 24 inches apart and at a depth of about 24 inches. Usually a section 100 or more feet in length is excavated at one firing. It is usually necessary to smooth the walls and bottom sufficiently to remove the high and low spots which would cause the formation of pools.

Ditch digging with dynamite, where practicable, is rapid and economical, and has the further advantage that the dirt

which would otherwise form spoil banks is distributed over the terrain. It is not a feasible method for use in dry soils, or in the construction of small ditches or those which must be carefully graded.

Lined ditches. Where an open dirt ditch is in loose soil or where the flow in such a ditch reaches a high velocity, the bottom and sides may be rapidly eroded, increasing the difficulty and cost of maintenance and decreasing the effectiveness of the ditch in preventing mosquito breeding. Frequently, under these circumstances, it may be found advisable to line the ditch with some impervious material for the purpose of preventing erosion of the sides and bottom or caving of the banks. A well constructed lining also facilitates cleaning.

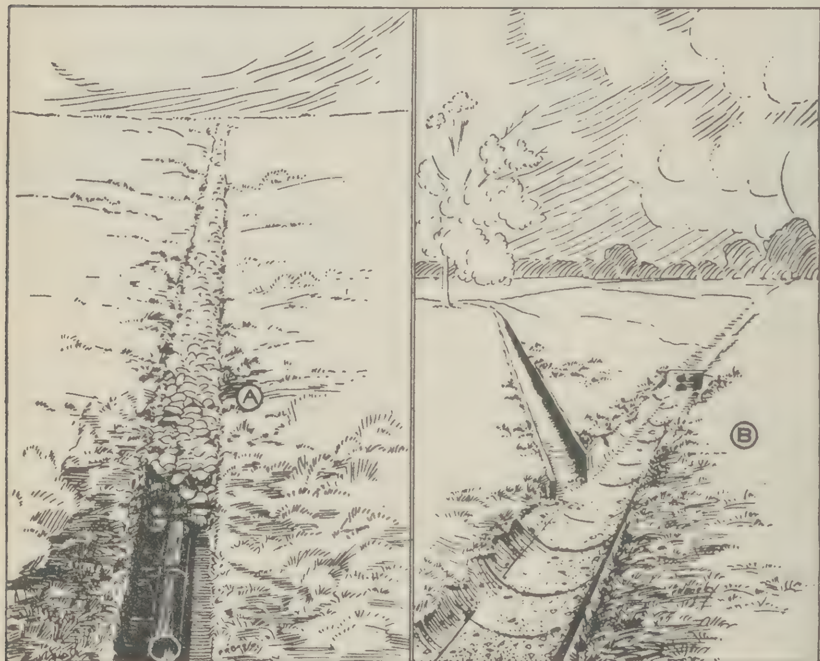


FIG. No. 287. Drainage ditches. A—Rock-filled tile ditch. B—Concrete lined ditch showing both sloping and vertical side construction.

Construction of linings. Ditches may be lined with concrete or with stones laid in mortar, preferably cement mortar. Usually, a lining which covers the bottom and extends up the sides to about three inches above the normal water line will

suffice and it is not necessary to extend the lining to the top of the ditch walls. At other times only the curves, turns and junctions need be lined (Fig. No. 287).

At sharp curves, the lining of the outer wall should be raised high enough to prevent scouring by an overflow of storm water. Also, where the current from a branch ditch strikes the opposite side of the main ditch, the ditch lining may be raised or a splash wall installed to prevent erosion of the earth and the formation of potholes.

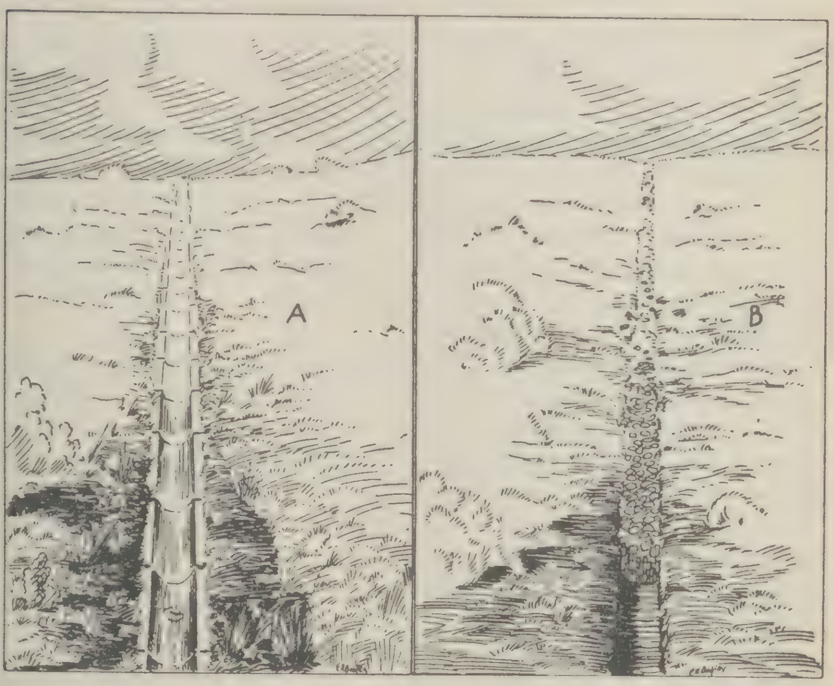


FIG. No. 288. Drainage ditches. A—Precast or sectional concrete lining. B—Rock-filled ditch without tiling.

If stones are used for lining, fairly large flat stones should be selected for this purpose. The interspaces should be filled with smaller pieces and the whole sealed with cement mortar.

Continuous concrete lining may be constructed by the use of forms. Where the ditches are less than two feet in width, the concrete lining should be about two inches thick and reinforced with two inch mesh poultry wire. Wider ditches should have proportionately thicker walls. The concrete may

be mixed with gravel or small stones and a smooth finish is not necessary. Seepage holes of suitable size should be made in the lining wherever it is probable that water will accumulate or flow behind the lining. The seepage holes should be directed downward and inward through the lining towards the bottom of the ditch and, where concrete is used for lining, they should be made before the concrete hardens.

Precast, sectional concrete lining may be used in lieu of the continuous lining. The sections are hemicylindrical in shape and usually from thirty to thirty-six inches long and from twelve to sixteen inches in diameter. The sections may be joined by interlocking male and female ends or the bell and socket union may be employed (Fig. No. 288).

The sectional lining gives better service than the continuous lining, and is much cheaper where the ditching project is sufficiently extensive to justify the installation of a plant for manufacture of the sections. Sectional linings have the further advantage that if for any reason a ditch is no longer required, the sections can be salvaged and used elsewhere in the construction of other ditches.

Ditches which are to be lined with either sectional or continuous concrete lining should be carefully graded.

Maintenance of ditches. All ditches should be cared for in such a way that they will not constitute breeding places for mosquitoes. In the temperate zone, they should be repaired in the spring of the year before the first mosquitoes appear and maintained in good condition throughout the summer months. In the tropics, maintenance work must usually be continued throughout the year.

Any conditions which cause the formation of pools or puddles or which retard the flow of water should be corrected. This is accomplished by keeping the banks smooth and in proper alignment, by removing all obstruction to the flow, such as debris, or accumulations of silt and mud, and by maintaining the proper grade.

In unlined ditches, the current may erode the bottom so that portions are below the grade. When the flow of water ceases, these depressions will retain water and provide breeding places for mosquitoes. They can be drained by digging a temporary channel with a hoe or spade or, in a muddy ditch, by dragging a small log or other suitable object down the

ditch. When the ditch becomes dry, the grade should be restored.

Unlined ditches in soft earth may be damaged or destroyed by heavy rains which cause caving of the sides and filling of the ditch with mud or debris. Cattle or horses may trample down the walls of the ditch and destroy its usefulness. Unless promptly corrected, the conditions thus produced will provide many breeding places for mosquitoes and may result in a worse situation than that which the ditches were installed to correct.

The growth of algae in ditch water, especially in large ditches, may be sufficient to provide shelter for larvae. Algae can usually be destroyed by the application of copper sulphate at the rate of one part per million (about 8 pounds of copper sulphate to one million gallons of water). This quantity of copper sulphate will kill many fish and should not be used if it is desired that fish be preserved.

In so far as practicable, all vegetation should be removed from the ditch. Vegetation in the water retards the flow and shelters the larvae. Where the control measures are directed against those species which breed in the sun (page 911), all vegetation which will shade the water in the ditch should be allowed to remain in place. In some instances bushes or brush which will shade the water may be grown along the banks of a ditch as a means of preventing the breeding of mosquitoes in the ditch.

The loose debris and algae may be removed from either concrete lined or small earth ditches by dragging a heavy oil soaked ball or mop made of old rope or sacking along the ditch channel. Mosquito larvae are deprived of shelter and the mop leaves a film of oil on the water and the sides of the ditch.

Subsurface drainage. Subsurface or subsoil drainage lines, consisting of covered tiles or rock filled ditches, may be used to drain away surface water as it is absorbed into the ground, to lower the level of the ground water so that the soil will more readily absorb the surface water, or to intercept seepage planes and prevent seepage water from forming pools on the surface of the ground.

Tile drainage. The tiling used varies in size from three to twelve inches, usually from four to six inches, in diameter. The

lines are usually laid in the general direction of the grade and from 50 to 150 feet apart. The average depth of the tiling is from two to four feet below the surface, but the depth at which the tile is laid and the distance between lines will vary according to the topography and other local conditions. As a rule, the closer a subsurface drain is to the surface of the ground the more rapidly it will drain away the surface water and the smaller the area which it will drain.

The tiles are laid in the bottom of a carefully graded trench the slope of which should be not less than three inches per 100 feet. The trench is back filled and the tiling covered with earth, gravel or graded rock. Gravel or graded rock filling facilitates the rapid removal of storm water. If graded rock is used, the larger sizes are placed in the bottom of the ditch around the tiles and the finer grades at the top. The filling should be carried to a height of several inches above the level of the ground (Fig. No. 287).

Rock filled ditches without tiling. Subsurface drainage may be accomplished by trenches back filled with graded rock, or relatively large stones, but without tiling. The trenches are usually dug from 12 to 24 inches in depth and about the width of the spade or shovel used in digging. The rock used for filling should be from two to six inches in diameter and, if graded, the larger sizes should be placed on the bottom (Fig. No. 288).

Rock filled ditches of this type are suitable for draining away slowly accumulating collections of water, such as are found in spring fed marshes. Cost of maintenance is low, as the rock filling prevents erosion and caving of the ditch walls.

Double decker drains. The so-called "double decker" drain has proven of value in draining areas where there is a flow of water at all times but where the volume of water during the wet season is too great to be carried by the ordinary tile drains. The double decker drain consists of a ditch on the bottom of which six or eight inch tile is laid in the usual manner. Instead of completely back-filling the ditch, ordinary sectional, concrete ditch linings (*supra*) are laid on top of, or immediately above, the tiling. The dry weather flow is carried by the tile line while the wet weather flow is drained away through both the tile line and the superimposed open, concrete lined ditch.

Intercepting drains. Occasionally subsurface tile lines are installed for the purpose of intercepting the flow of seepage

water. Seepage water is ground water (spring water) which is forced to the surface of the ground by the position of the underlying impervious stratum. Seepage areas usually occur on the side of a hill but may be found in other localities. The seepage water usually collects in small pools or puddles, or produces a marshy area, in which mosquitoes may breed in large numbers. An intercepting drain, which consists of a tile line covered with graded rock (*supra*), is laid at approximately right angles to the direction of flow of the seepage water. It should be located above the point of the maximum flow of the seepage outcrop, as determined by inspection during or soon after a heavy rain.

Maintenance of subsurface drains. Well constructed subsurface drains require but little attention, although occasional inspections should be made for clogging. It may be necessary to provide protection where traffic passes over a tile line. Ordinarily, no cleaning or regrading is required.

FILLING

Depressions and low areas which serve to collect and retain water in which mosquitoes breed may, in some instances, be permanently eliminated by filling. Filling may also be employed to reduce the amount of water in areas which are below grade and difficult to drain and thus facilitate other control measures. Filling may also be employed to eradicate accidental collections of water in small depressions, such as wheel ruts, hoofprints or holes, and pits resulting from construction work.

Filling is usually a quite satisfactory method of treating low areas or depressions of varying sizes in which rain water tends to collect, but can be seldom utilized successfully to cope with collections of seepage water. Filling permanently eradicates the breeding places and it has a further advantage over open drainage that no maintenance work is ordinarily required. At times it will be found that, while the first cost is greater, filling is ultimately the cheapest and the most effective method of controlling mosquito breeding in a given area.

Construction of fills. Large fills are ordinarily made of earth and rock, but waste materials, such as garbage, rubbish, sawdust, cinders, or ashes, may be utilized, at least in part, as filling material. Ashes and cinders, preferably mixed with

earth, make a very satisfactory filling material for small depressions.

A small number of men equipped with shovels and picks can eliminate many slight depressions in which water would otherwise collect and provide breeding places for mosquitoes. Larger fills will require more elaborate equipment, such as animal or tractor drawn scrapers or even steam shovels.

STREAM TRAINING

A small stream frequently offers ideal breeding places for certain species of Anopheles and Culex mosquitoes. The more or less still water in the holes and depressions in the banks, at the bends in the stream, and in the backwash from eddies provides places in which larvae can develop, protected from currents and sheltered by vegetation and flotage from their natural enemies. These breeding places are eradicated or made unfavorable for mosquito breeding by stream training. In stream training, where practicable, the bends in the stream are straightened and marginal depressions are removed by filling, draining or regrading. The stream bed may be narrowed or even regraded in places to increase the velocity. The vegetation and debris in the stream bed, which might retard the flow or shelter the larvae, should be removed. Where species which prefer to breed in the sun are present, any vegetation on the banks that will shade the water in the stream should be allowed to remain (page 911).

ELIMINATION OF ARTIFICIAL WATER CONTAINERS

The control of breeding places of *Aedes egypti* and *Aedes albopictus* is, for the larger part, a question of eliminating or treating water in artificial containers. Culex, and sometimes Anopheles, will also breed in these places.

All empty tin cans should be crushed so that they will not hold water before being disposed of on dumps or other places in the open. Barrels, buckets, or other receptacles in which water stands should, if practicable, be emptied and dried in the sun at least once each week. The water in fire buckets may be treated with a phenol larvacide. When vessels of water are

emptied, care should be taken to remove or destroy the eggs and larvae on the sides and bottom before refilling.

Special attention should be devoted to rain gutters in which small accumulations of leaves or other debris will form dams behind which water will be retained. These collections of water are favorite breeding places for *Aedes egypti* and will produce large numbers of mosquitoes in a short time. During the rainy season, all rain gutters should be inspected and cleaned, if necessary, once each week.

Where it is impracticable to empty the water, as in the case of cisterns, tanks of various kinds, shallow wells, ornamental basins, and fountains, the water should be treated with a larvacide, or stocked with fish. If practicable, the adult insects should be excluded by screening. Cisterns or tanks containing water for domestic purposes should be well screened.

Effective control of mosquito breeding in artificial collections of water can be maintained only by thorough and repeated inspections. Some person or persons should be made responsible by proper authority for the conduct of such inspections, and the inspections should be made routinely at designated intervals.

OILING

When properly spread over the water, oil produces a film which kills mosquito larvae and pupae. The lethal effect of oil is probably due to the toxic action of volatile gases after inspiration of the oil into the tracheal tubes. A highly volatile oil is highly toxic and a non-volatile oil is non-toxic. Consequently, the ability of an oil to kill larvae and pupae, and therefore its value as a larvacide, is proportionate to and determined largely by its volatility. Oils which have a boiling point between 200° and 500°F. have been found to kill larvae and pupae by direct toxic action in about 30 minutes. A thick film of non-toxic oils may kill by suffocation but it is difficult to maintain such a film intact for a sufficient period of time.

Oil larvacides consist, generally, of crude oil or waste motor oil, either of which may be diluted with kerosene. Crude oil, or fuel oil, is larvacidal in its action but the heavier grades will not spread and produce a film on the surface of the water, especially during cool weather. Light crude oil which has a specific gravity of from 0.85 to 0.87 spreads readily and will form a

satisfactory film in any temperature suitable for mosquito breeding. Kerosene may be used to dilute the heavier oils so that they will spread to form a film. The proportion of kerosene required varies from 20 to 75 per cent, depending on the viscosity of the crude oil.

Kerosene alone may be used as a larvacide, but it evaporates rapidly, the film is fragile and easily broken, and it is usually too expensive for routine use.

Waste motor oil or other waste oils may be used as a base in lieu of the crude oil. Motor oil is relatively non-volatile and is therefore non-toxic. It will kill larvae and pupae only when the film is sufficiently thick and intact to prevent them from reaching the air. As it is difficult to maintain such a film, the best results are obtained when the motor oil is mixed with and diluted by kerosene in the same manner as crude oil. The resulting product is apparently as efficient in the destruction of larvae as crude oil and, where the waste oil is available, it is considerably cheaper.

The spreading quality of any of the oils is greatly increased by the addition of two per cent of crude castor oil.

Application of oil. Oiling is essentially a temporary measure and must be repeated at intervals, the length of which is determined to some degree by the weather conditions, the kind of oil used and the character of the water. In order for oil to be effective it must form a thin tenacious film which will remain in place on the surface of the water long enough for larvacidal action to occur. The oil may fail to spread or the film may soon be destroyed by rain or wind, by evaporation, or by currents. If light oil is used, the film is more easily broken and dispersed. As the larvae will develop in from a week to ten days in warm weather, the oil should be applied at intervals of approximately one week. In colder weather, the period between oilings may be lengthened to possibly as much as three weeks.

The quantity of oil required to produce a film over a given area depends to a very considerable extent on the viscosity of the oil and the amount of vegetation present. A film of toxic oil which is iridescent in the sunlight is thick enough to kill mosquito larvae. Under the most ideal conditions, in quiet waters containing no vegetation or debris, three to five gallons of a light, well spreading oil will produce a thin but

satisfactory film over an area of one acre (4840 square yards). Under the ordinary conditions, using an oil of average viscosity, as much as thirty gallons of oil is frequently required to produce a satisfactory film over an area an acre in extent. For smaller areas, about one gallon is usually required to cover an area of from 100 to 200 square yards. Where vegetation is present, the oil should be applied in such quantity and in such manner that the water around and under the vegetation will be covered as completely as practicable. In many instances, it is extremely difficult to produce a satisfactory film where the oil must spread through vegetation.

In order to kill all the larvae, or at least the greater proportion of them, the film should remain unbroken for a period of several hours. The film may be washed away by currents, broken up by rain, or blown to one side by the wind and, consequently, oil is ineffective as a larvacide if conditions are such that the film will not remain intact long enough to kill the larvae.

Various methods are available by which oil may be applied to the surface of water. The particular method selected will depend on the kind of water to be oiled, that is, small collections of standing water, ditch water, running streams, or large bodies of water such as ponds or lakes.

Oil may be effectively applied to small collections of water by means of an oil soaked broom, an oil mop or oil soaked cloths tied to a stick, or similar contrivances. The ordinary watering pot used for watering plants may be used to oil small collections of water, or the oil may be poured on the surface of the water.

Sprayers are usually employed in oiling larger bodies of water. Where continuous application is desired, continuous oilers of either the drip or submerged type are used.

Sprayers. The knapsack sprayer consists of an oil container, hand pump and spray nozzle, and is carried and operated by one man. The ordinary sprayer has a capacity of about five gallons and a spraying range of about 25 feet. The knapsack sprayer is a practical and economical apparatus for applying oil to ditches, small ponds, or other collections of water which can be reached by the spray (Fig. No. 289).

Larger sprayers may be employed to oil extensive areas such as the borders of large lakes or, in some instances, large

FIG. No. 289. Method of using knapsack sprayer for the application of oil.

swampy places. Such a sprayer usually consists of a barrel or tank container and a pump mounted on a vehicle or in a boat. Large bodies of water, such as the borders of lakes or impounding reservoirs, may be oiled by the "water-oil" method. A centrifugal pump mounted in a boat and operated by the motor of the boat is used to project a stream of water and oil for some distance, usually 60 to 100 feet, over the surface of the water. The water is drawn from the lake and the oil is drawn from storage tanks into the suction line of the pump. This method permits oil to be forced into spaces around vegetation or flotage and, also, to spray the oil against a breeze.

Continuous oilers. Where the oil is dispersed by currents, as in streams or ditches, a film can be maintained only by the constant application of oil. Either a drip or submerged oiler may be used for this purpose. Continuous oilers have many disadvantages and their use is feasible and practicable only in selected situations where a film cannot be economically maintained by other methods.

FIG. No. 290. Drip oiler made from standard galvanized iron can with wick in the side.

Drip oilers. The drip oiler consists of an oil container, such as, for example, a five gallon oil can or a small drum, which is placed on supports over the stream or ditch so that the oil will drip through an outlet onto the surface of the water below. The container should be placed several feet above the surface of the water so that the oil will spread quickly when the drops strike the water (Fig. No. 290).

The rate of flow from a drip oiler may be regulated in one of several ways. The simplest regulator consists of a nail of suitable size passed through a perforation in the bottom of the can which is slightly larger than the diameter of the nail. The nail is wrapped with cotton, thin cloth or gauze and the wrapped portion wedged into the perforation. The flow can then be regulated by gently moving the nail up or down until the desired rate is attained. More elaborate regulators, consisting of stop cocks, faucets, pinch cocks or flexible tubing or wicks, may be employed. However, any type of regulator requires attention to prevent interference with the flow by sediment in the oil and by changes in temperature.

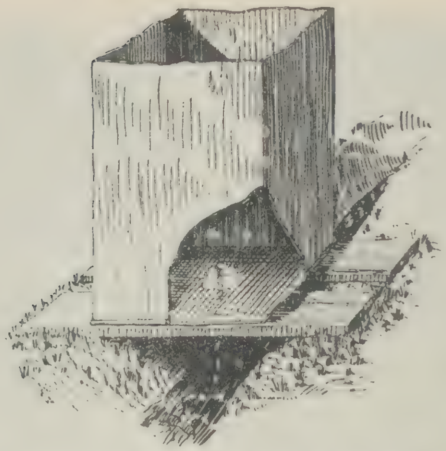


FIG. No. 291. Drip oiler made from five gallon oil can. Regulator consists of nail and cotton plug. Suitable for oiling water in a small ditch.

In order to maintain a continuous film of oil on the running water, the required rate of flow will vary according to the width of the stream, the grade of oil, the spread attained, the velocity of the current, the alignment of the stream or ditch, the roughness of the banks, the amount of algae in the water, flotage in the water, or weather conditions, and must be determined by trial in each case. Generally, an average flow of from 10 to 20 drops per minute will suffice for each foot of width of the water in the stream or ditch. At times where the stream is sluggish, it may not be necessary to maintain a continuous flow and the flow may be intermittently stopped or decreased.

Where supports for the drip oiler cannot be installed because of the width of the stream, flooding, or for other reasons, the oiler may be placed on a moored raft or float.

The drip oiler can be used to the best advantage where it is desired to maintain a film on the water in indentations, eddies, and quiet places along the borders of a ditch or small stream. It may be used to apply oil to the surface of a stream so that it will be transported by the current to otherwise inaccessible pools formed by the stream or into which the stream empties. The drip oiler has the great disadvantage that it requires more or less constant attention and the flow is difficult to regulate and maintain.

Submerged oilers. A submerged oiler is a container having two small openings and so designed that when sunk to the bottom of the stream or pond the oil will escape through one opening and be replaced by water which enters through the other. The oil then rises to the surface and forms a film.

A number of different kinds of submerged oilers have been designed but an effective and cheap device can be made from an oil can (one or five gallons). A small hole is punched in the bottom, or the lower part of the side of the can, and another in the top. The can is filled with oil and submerged by means of an attached weight or rock of sufficient size to overcome the buoyancy of the oil. When the oiler is submerged the oil being lighter than water will escape through one of the openings while the water enters through the other, the rate of flow being governed by the size of the openings. Any similar container may be used instead of an oil can, but it should have an opening, such as a screw top, which can be closed after filling. The oiler may be recovered when empty by means of a light line attached to the bank or to a float.

Submerged oilers have the disadvantage that they are difficult to adjust so that the oil will flow properly. A small outlet opening is easily clogged by sediment while a large opening tends to cause wastage of oil.

Oilsoaked sawdust. Oil may be applied continuously by means of a submerged bag of oilsoaked sawdust. A sack of suitable size is filled with sawdust and the whole soaked with oil larvacide. Stones or rocks are used to weight the bag. The oil will be given off gradually and maintain a film for a considerable period of time.

A satisfactory film can be produced by scattering oilsoaked sawdust on the surface of the water in small ponds, puddles, or hoofprints.

PHENOL LARVACIDES

Phenol is toxic for mosquito larvae and various phenol compounds are used as larvacides. The so-called *Panama larvacide* is made by mixing crude carbolic acid, resin and caustic soda in the proportion of five gallons of crude carbolic acid, six pounds of finely crushed and sifted resin and one pound of caustic soda. The product is a black, liquid resin soap that

emulsifies freely with fresh water. The carbolic acid is heated in an iron container until it is steaming hot, the resin is added and the solution stirred with a paddle until the resin is completely dissolved. The caustic soda is dissolved in a pint of water and added to the carbolic acid and resin solution. The heating and stirring are continued for about 5 minutes. A sample of the mixture is then poured into water and if a complete emulsion results, the larvacide is ready for use. If the mixture does not emulsify in water, or the emulsion is incomplete, the heating and stirring are continued until a satisfactory emulsion is obtained. The crude carbolic acid should contain not less than 15 per cent of phenol and have a specific gravity of not more than 0.97.

The Panama larvacide is prepared for use by mixing one part of the larvacide with five parts of water. The resulting emulsion is applied by spraying, or in the case of small collections of water, a watering pot may be used or the larvacide may be poured into the water. The larvacide should be applied in such amounts that an emulsion with the treated water of from 1 to 1000 to 1 to 10,000, preferably about 1 to 5,000, will result. An emulsion of 1 to 5,000 will kill the larvae in about 10 minutes. The Panama larvacide can be used wherever hand oiling is feasible. As it kills the greater proportion of the larvae, it need be applied only at such intervals as will prevent complete larval development. This interval is usually one week but may be as long as three weeks.

When properly made and applied, the larvacide spreads evenly and rapidly through the water, poisoning the larvae on contact. It is not necessary, as in the case of oil, that the larvae rise to the surface of the water to make contact with the larvacide. This larvacide is also an effective algicide and by killing the algae deprives the larvae of food and protection. The emulsion deteriorates on exposure to air and loses its effectiveness after about 24 hours. Contact with algae and other organic matter also reduces its larvacidal power.

The Panama larvacide possesses the additional advantage that, when frequently applied, it will kill the grass and vegetation growing in the water. It has the disadvantage that it may be detrimental to small fish and prove harmful to domestic animals.

An emulsion of one part of *cresol* in five parts of water may be used as a larvacide in the treatment of pool waters. It is applied in the ratio of one part of the emulsion to from 5,000 to 10,000 parts of the water to be treated. The emulsion must be well mixed with the water in the pool.

PARIS GREEN LARVACIDE

Paris green containing not less than 50 per cent of arsenious oxide is a cheap and very effective Anopheles larvacide. It is applied in the form of a mixture of minute particles of paris green with finely pulverized inert material. Only a fraction of the paris green compound is water soluble and, consequently, the particles are held in the surface tension layer of the water where they are accessible to and are ingested by the surface feeding Anopheles larvae. As the particles must be ingested, paris green does not kill the first stage larvae or the pupae of Anopheles. Paris green is not ordinarily effective against the larvae of genera other than the Anopheles because the particles do not remain in that part of the water in which these larvae feed.

Preparation of the paris green larvacide. The paris green larvacide is prepared by mixing the chemical in varying proportions with an inert dust. The diluting dust may consist of hydrated lime, finely pulverized dry earth (road dust), powdered limestone, soapstone, ashes, or stearates of calcium and aluminum. The dust should be fine enough to be carried by a light wind, but not so fine that it will not eventually settle on the water. Hydrated lime is the most satisfactory diluting dust for all purposes, but soapstone, which is heavier than lime, may be used where quick settling onto the water is desired. If soapstone is not available, it may be found desirable to add a small quantity of clay or coarse sand to prevent undue dispersion. If a long floating period is desired, a diluent that is lighter and less soluble than hydrated lime should be used. The stearates of calcium and aluminum have been found to be most effective in prolonging the floating period.

Usually, where the larvacide is to be applied by hand, it consists of one part of paris green mixed by volume with 99 parts of the diluent. Where the larvacide is to be applied by mechanical dusters, or large areas are to be treated, it

should contain a larger proportion of paris green. The relative proportion of paris green should also be increased wherever there will be considerable wastage because of wind or wet or heavy vegetation, or if the dust is to be applied from an airplane. Under these conditions, a mixture containing from 5 to 25 per cent by volume of paris green in hydrated lime should be used.

The paris green and diluting material should preferably be mixed by mechanical means. One device for this purpose consists of a dust tight box, keg or small barrel, mounted on a diagonal axis in such a manner that it can be rapidly revolved. If no mechanical mixer is available, the mixture may be made with a shovel or paddle.

FIG. No. 292. Method of producing dust cloud of paris green larvacide with hand operated dust blower.

Application. The paris green mixture can be applied to ponds, lakes and the larger streams by tossing the dust into the air from the windward side so that it will form a cloud and be carried out over the water. The large hand or motor operated dust blower ordinarily employed for dusting trees in horticultural work may be used to throw the dust into the air. For large bodies of water, a slowly settling dust cloud

carried along by a light wind will give the best results. In the case of small bodies of water where vegetation is heavy, or ditches and streams which are too narrow to be dusted by the cloud method, handfuls of the dust should be thrown directly on or into the vegetation or onto the surface of the water. A hand dust blower, such as is used for dusting insect powder on plants, can be used. Airplanes may be used to apply the dust over large areas, such as extensive swamps. Generally, the best results will be obtained on a sunny day after the dew has evaporated from the vegetation in the water.

While the amount of larvacide required to treat an area of given size will vary according to the amount of vegetation present, it has been found that when the surface of the water is clear, or only covered with low vegetation, about one-half ounce of paris green when mixed with 100 parts of dust is sufficient for 1000 square feet of water surface. Greater quantities must be used where the water is covered with vegetation such as grass or reeds, or where it is applied with mechanical dusters or from an airplane.

The paris green larvacide will kill the second, third and fourth stage Anopheles larvae within a few hours and need be applied only at such intervals as are necessary to prevent the development of the remaining first stage larvae or of new broods of larvae. Under the average conditions, paris green should be applied at intervals of from four to seven days in warm weather. Dusting should be repeated without delay whenever examination of the water reveals the presence of fourth stage larvae.

Advantages and disadvantages of paris green. When properly prepared and applied, most of the diluting dust will sink in the water or be dissolved, leaving the particles of paris green on the surface where they can be reached and ingested by the Anopheles larvae. The water treated with proper amounts of paris green larvacide will not harm domestic animals nor is the larvacide detrimental to fish. The men distributing the paris green larvacide should stand to windward of the cloud, but, in any event, the amount of arsenic ordinarily used is so small that there is little or no danger that those handling it will be poisoned.

The toxicity of paris green varies and each lot should be tested for its lethal action on mosquito larvae before being

FIG. No. 293. Method of applying paris green larvacide to water covered with vegetation.

used for field work. The test may be made by placing larvae in pans and dusting with the compound being tested, using a 1 to 100 dilution. If the paris green is sufficiently toxic for use as a larvacide, all the larvae in the test pans should be killed in a short time.

The paris green larvacide is cheap and easily transportable, as compared with oil and phenol larvacides. It can often be effectively applied over areas such as swamps and marshes which are difficult to treat with a liquid larvacide. It is easy to apply by utilizing the wind for distribution and, if properly used, it is not detrimental to men, animals or fish.

Paris green has the great disadvantage that it does not, as ordinarily employed as a dry dust, destroy the larvae of any genus except Anopheles. It is not, therefore, an effective larvacide where it is desired to destroy larvae of other genera, as well as Anopheles larvae. Also, as paris green does not destroy all of the first stage larvae or any of the pupae of Anopheles, it must be applied at more frequent intervals than oil. Paris green has the further disadvantage that the dust is difficult to handle and apply during rainy or excessively humid weather.

Paris green larvacide for Culex and Aedes. Experimentally, or in selected situations, paris green can be employed to destroy larvae that feed below the surface of the water or at the bottom, such as Culex and Aedes. In order for the paris green to be accessible for ingestion by these larvae, it must be carried below the surface of the water and this can be done by the use of a mixture of paris green and moist sand. The particles of paris green adhere to the moistened grains of sand which are sufficiently heavy to sink in the water and thus carry the paris green below the surface and to the bottom.

The paris green and moist sand larvacide can be used to the best advantage in the treatment of water contained in relatively shallow, artificial receptacles in which Culex or Aedes breed. Some of the particles of paris green will float on the surface of the water and serve to destroy any Anopheles larvae that may be present.

The paris green and moist sand are mixed in the same proportion and in the same manner as when dry dust is used as a diluent.

DESTRUCTION OF LARVAE BY NATURAL ENEMIES

The natural enemies of mosquito larvae consist of fish, certain aquatic insects, especially the larvae of dragon flies and may flies, and species of mosquito larvae having cannibalistic tendencies. In nature, however, a natural balance is always established which prevents the destruction of all mosquito larvae by their natural enemies. Only when the environmental conditions are so modified by man that the natural balance is wholly or partially eliminated can control of mosquito larvae be effectively accomplished by their natural enemies.

Fish are the most important of the natural enemies of the mosquito which can be employed in the control of mosquito breeding. While many fish will consume mosquito larvae and pupae, the top feeding minnows are most effective for this purpose, especially in the control of Anopheles. In some instances, bottom feeders may be more effective than surface feeders in destroying larvae, such as Aedes larvae, which tend to seek the lower depths or the bottom of the breeding water. A number of different genera and species of fish have been

found to be of value in mosquito control work. The fish selected should be indigenous to the locality in which they are to be used. Because of its geographical distribution, adaptability to different waters, breeding habits, and a tendency to consume comparatively large quantities of animal food, *Gambusia affinis* is the most efficient minnow for mosquito control in the United States.

Gambusia affinis is grayish silver in color. The female is much larger than the male, attaining a length of from two to two and one-half inches.

Gambusia affinis is to be found in all states east of the Rocky Mountains and south of Delaware and Illinois. However, while it is widely distributed geographically, locally it is found principally in lowland waters. It inhabits ponds, sluggish streams and ditches, and is essentially a still water fish. It thrives in fresh or brackish water, in turbid or clear water, in water containing domestic sewage, in ponds and streams that are visited by domestic animals, and in cisterns, water tanks, potholes or barrels. It avoids deep water where there are predaceous fish or where food is scarce, showing under such circumstances a distinct preference for shallow water or the shallow parts of ponds and streams. It does not inhabit, naturally, swiftly flowing streams or water polluted with trade wastes of an acid nature.

Gambusia affinis feeds almost solely on food floating at or near the surface of the water. It will not search for food below the surface as long as there is a supply at the surface. It prefers live food, particularly moving prey, and subsists upon insects, especially the larvae and pupae of insects, when such food is available. *Gambusia affinis* will, however, consume other food and, if other food is obtainable, it will thrive even if insects and their larvae are not available.

Use of Gambusia in mosquito control. While *Gambusia affinis* occurs naturally in many waters, frequently they are insufficient in numbers to eradicate the mosquito larvae, and because of natural enemies, such as predaceous fish, and their own cannibalistic instincts, they do not increase beyond a certain maximum number.

Gambusia affinis may prove to be of considerable value in the control of mosquito breeding in ornamental basins, ponds or lakes or other bodies of water where the use of a larvacide is un-

desirable. Ordinarily, however, in natural waters, larvivorous fish cannot overcome the natural balance which operates to maintain the insect species despite natural enemies and are, therefore, inadequate as a sole anti-mosquito measure.

The Anopheles larvae attempt, instinctively, to hide from larvae eating fish and the presence of vegetation or flotage in the water which will afford hiding places for the larvae will lower the efficiency of *Gambusia affinis* in maintaining mosquito control. If *Gambusia affinis* are to be used for mosquito control, the vegetation and flotage which would protect the mosquito larvae should be removed or reduced to a minimum.

REPELLENT VEGETATION

Apparently, some species of mosquitoes will not breed in water containing certain aquatic plants. These plants may serve to repel the adult mosquitoes and prevent oviposition, or render the water unsuitable for larval development. It has been observed that *C. pipiens, C. territans, Aedes vexans* and *Anopheles punctipennis* will not develop in water containing *Chara fragilis.* In other instances, it has been found that Anopheles larva are consistently absent from waters containing certain other plants, particularly where the water is completely covered. These plants include wild ginger, smart-weed and duckweed.

DESTRUCTION OF ADULTS

Female Anopheles and Culex mosquitoes enter human habitations only for the purpose of securing blood, and having obtained a blood meal, immediately seek dark, shady resting places on the outside. As these genera bite normally only during dusk or the hours of darkness, they are not commonly found in large numbers in buildings during the day, if it is possible for them to escape to the outside.

As Anopheles are unable to withstand the effects of the direct rays of the sun or high winds, they avoid sunlight and seek shelter from the elements in vegetation, such as leafy plants, weeds, high grass or brush.

Aedes egypti will breed in inhabited houses and will not endeavor to escape from the building after obtaining a blood meal. It is a daytime biter and hides in out of the way places at night.

Because of these habits, particular attention should be devoted to the destruction of the adult mosquitoes in inhabited buildings. This is especially important if a case of dengue or yellow fever has occurred in the building.

The destruction of the adult mosquitoes can be accomplished by attacking them within buildings by spraying, fumigation, swatting or hand catching, and in the open by clearing away the vegetation which protects them from the sun and wind.

Spraying. Spraying is the most efficient method of killing the adult mosquitoes inside of a room or building. The pyrethrum sprays described on page 807 are the most effective for this purpose.

Fumigation. Fumigation is not ordinarily a practicable method of destroying Anopheles or Culex, but is a valuable measure for the control of *Aedes egypti.* It may be used in screened buildings which have become infested with a large number of mosquitoes, provided such buildings can be made reasonably airtight. Barracks containing large numbers of Anopheles or *Aedes egypti* should be fumigated, particularly if it is suspected that the mosquitoes are infected.

Sulphur is the most practical fumigant for use at army stations. The buildings should be prepared for fumigation by closing all crevices and cracks in the walls, ceilings, window casings or doors, with strips of pasted paper. The sulphur is applied at the rate of two pounds for each 1000 cubic feet of room air space. It is placed on crumpled paper in an iron pan or pot and, to lessen the fire hazard, the pan or pot is placed in another vessel containing water. A little kerosene or gasoline is poured over the sulphur and ignited. The rooms or buildings being fumigated should not be opened for at least two hours. Pyrethrum may be used in lieu of sulphur. It is applied in the same amounts and by the same method as sulphur.

Swatting. Fly swatters may be used to kill mosquitoes resting on the walls and ceilings. This method has the disadvantage that the blood in engorged insects killed by swatting will stain the surface upon which they are resting. Also during the day Anopheles or Culex that cannot escape from the buildings usually hide in crevices, corners, under shelves and similar places, where they cannot be reached with a swatter. During the twilight hours and just after daybreak, the Anopheles mosquitoes

tend to collect on the screening of doors, windows, and porches where they can be easily killed with a swatter.

Hand catching. Hand catching, if systematically carried out, is an effective method of eradicating or reducing the numbers of mosquitoes within a building. Either a suction catching tube or a chloroform killing tube may be used to capture mosquitoes. The suction tube (Fig. No. 294) is used by compressing the rubber bulb and then placing the open, invaginated end of the tube over the resting mosquito. When the bulb is released, the suction draws the insect into the tube and the open end of the tube is then closed with a cotton plug. The captured mosquitoes may be killed with chloroform, or by jarring the tube against the hand.

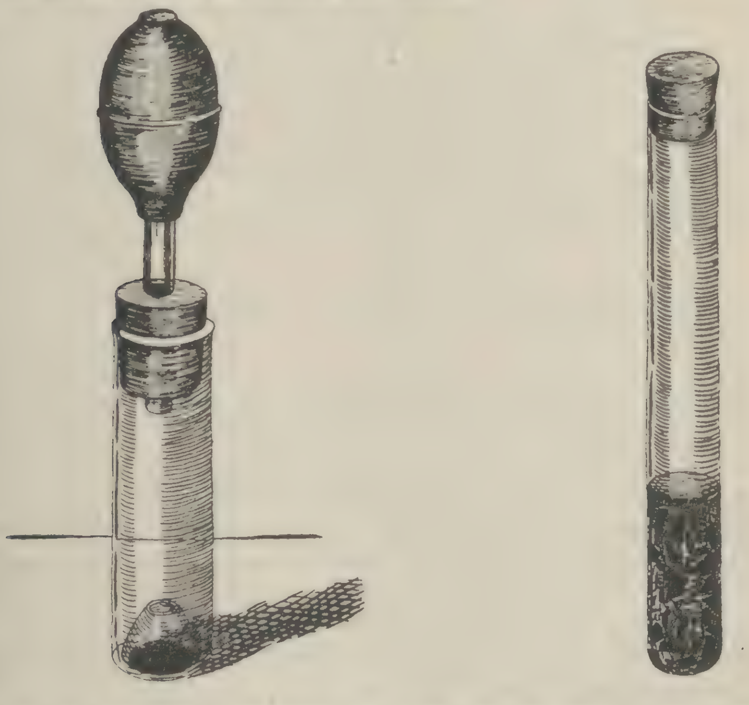


FIG. No. 294. Mosquito catching tubes. Left, suction tube. Right, killing tube containing rubber bands saturated with chloroform.

The killing tube is a glass tube, such as a large test tube, four to six inches long by one to one and one-half inches in diameter. A one-inch layer of small rubber bands is packed in the bottom of the tube and held in place by a disk of blot-

ting paper or perforated cardboard. The rubber bands are saturated with chloroform and the tube provided with a cork which can be easily removed with the fingers. A tube prepared in this manner will remain effective for killing mosquitoes for several days. It should be kept tightly corked when not in use.

The mosquito is captured with the killing tube by placing the open mouth of the tube over the resting insect. In a few moments it will be stunned by the chloroform fumes and drop to the bottom of the tube.

It is almost impossible to keep screened barracks entirely free of mosquitoes, as a few will always contrive to gain entrance through small defects in the screening and through the doorways when the screen doors are opened. During the day, all the darkened places, such as those behind pictures, clothing and other objects on the walls, under the window ledges and shelves, in closets, in remote corners and crevices, should be searched with the aid of a flashlight for the resting Anopheles and Culex. One man trained in finding the hiding places of the resting mosquitoes and in the use of a catching tube can do much to eliminate mosquitoes from barracks.

If captured mosquitoes are to be studied with a view to species identification, they should be kept dry and so handled as to avoid damage.

Clearing. Vegetation in the vicinity of inhabited buildings which will provide daylight resting places for the mosquitoes and protect them from the sun and wind should, where practicable, be removed. Such vegetation consists principally of grass, brush, and leafy vines and bushes. The removal of trees is seldom justified as an anti-mosquito measure, although they do provide protection for the adult mosquitoes.

Trees, brush or other vegetation in the vicinity of Anopheles breeding places which will shade the water should not ordinarily be removed as many species breed by preference in sunlit rather than in shaded waters.

SCREENING

Troops may be protected from the bites of mosquitoes by the screening of all windows, doors and other openings in barracks and quarters, or by the use of mosquito bars. The effectiveness of wire screening in excluding mosquitoes from inhabited buildings depends upon the kind of metal used, the size of the mesh, and the proper repair and maintenance of the screens. In the case of poorly screened buildings, mosquitoes may gain entrance through openings in the screening and, having secured a blood meal, be unable to escape. Such a building serves as a mosquito trap and a considerable number of the insects, some of which may be infected, are forced to remain in the building from day to day.

Wire screening. The wire used in making metal screening should be hard drawn copper wire containing not less than 99 per cent of copper. Black enamel steel or galvanized iron wire will give satisfactory service away from the seashore in temperate climates, but copper wire should be used in the tropics and in coastal areas of the temperate zone. Under the latter conditions, iron or steel wire screening deteriorates rapidly and is difficult to maintain in a mosquito proof condition.

Wire screening necessarily interferes considerably with ventilation and therefore the mesh should be no finer than is required to exclude the local species of mosquitoes. In determining the mesh to be used, the diameter of the wire, as well as the number of wires to the inch, must be considered.

While a mesh of 16 wires to the inch will exclude Culex and Anopheles mosquitoes, it will not prevent the entrance of *Aedes egypti*. A mesh of 18 wires to the inch will exclude *Aedes egypti* as well an Anopheles, and should be used where the former are prevalent.

The following table gives the standards commonly employed in the United States in the manufacture of copper screening:

Grade	*Mesh*	*Diameter of wire*	*Size of aperture*
Regular	16	0.0113 in.	0.0512 in.
Heavy	16	0.015 in.	0.0475 in.
Regular	18	0.010 in.	0.0456 in.

If 16 wires to the inch mesh is employed, the heavy grade should be used in the tropics and the regular grade in the temperate zone.

Installation of screens. In the installation of screens, the construction and fitting should be such that no apertures will result from warping of the frames or faulty fitting. All screen frames should be made of well seasoned wood or of metal. Windows having a double sliding sash should have a full length, single piece screen with the frame fastened in place with nails or screws. Where fixed half screens are used, a space will be left between the window sash and the screen when the window is opened, especially if it is not fully opened. If an adjustable half screen is used for barracks windows, there is always a tendency for the men to open the screen and leave it open, or to open the window not covered by the screen. If the full length screen is held in place with hinges and catches, instead of being nailed or screwed fast, it will be opened and left open, unless strict discipline is maintained.

Screen doors should be braced to prevent warping of the frames, they should invariably open outward, and they should be equipped with springs which will close them quickly and forcibly. Doors which open inward will carry mosquitoes into the buildings, and those which close slowly and gently with check springs will permit easy access of the mosquitoes to the interior. Screen doors should close tightly against a broad surface, such as a batten, at both sides and both ends. Otherwise, openings will be left which will admit mosquitoes. The bottom of the door should close against a batten at least three-fourths of an inch high on the outside and beveled to the floor on the inside to permit sweeping. Close apposition of all surfaces cannot be attained by edge fitting.

The installation of screen doors and window screens should be accompanied by the closure or screening of all incidental openings which would admit mosquitoes into the interior. All cracks and crevices or apertures in the walls, floor or roof should be repaired or covered with screening or other material. Floor or porch drains which open to the outside should be closed or screened. Open fireplaces should be screened or closed in such a way as to prevent the entrance of mosquitoes.

Maintenance of screening. The female mosquito, when hunting for a blood meal, is strongly attracted by the occupants of a building and, urged by instinct, she will search diligently for an opening, however small, which will permit her entrance. It should be remembered that the Anopheles mosquito can enter, and probably will find, any opening one-fourteenth of an inch or more in diameter.

Metal screening can be maintained in a mosquito-proof condition only by constant inspection and the immediate repair of defects as found. In permanent stations, or wherever screened buildings are used to protect the personnel from the bites of infected mosquitoes, a routine screen inspection service should be maintained. A portion of the screening should be inspected each day and all screens should be inspected at least once each week throughout the mosquito season. Particular attention should be devoted to detecting small defects, such as broken or stretched wires, punctures, small rents and breaks in the screening where it is fastened to the frame. The large defects are easily found by casual inspection. The frames should be inspected for warping and sagging which will create openings large enough to admit mosquitoes.

In the temperate zone, where there are no mosquitoes during the winter months, all screening should be carefully inspected and repaired during the spring months of each year prior to the beginning of the mosquito season. Usually it is expedient and feasible to employ the same man, or detail of men, to inspect the screening and to catch the mosquitoes in the buildings (page 941).

Repairs. Repairs should be made at the time of inspection. Small rents, tears, punctures and breaks in the wires can be repaired with patches of wire cloth sewn on with fine copper wire, but care must be taken to avoid enlarging the spaces between the wires sufficiently to permit the passage of mosquitoes. Where large rents are present or a portion of the screen is missing, the entire width should be replaced with new wire cloth. Extensive patches are seldom satisfactory.

It may be advisable to paint screening, particularly that made of steel or iron wire, to prevent deterioration from rusting. A very thin paint should be used, as it is difficult to apply the paint so as not to decrease unduly the size of the apertures. Paint may also be used for the purpose of reduc-

ing the area of the spaces between the wires. Screening in which the apertures are otherwise too large to prevent the passage of the smaller mosquitoes, such as Anopheles and Aedes, may thus be rendered mosquito proof. One or two coats of paint may be applied to reduce the aperture area of 14 wires to the inch mesh to that of 16 wires to the inch, or to reduce that of the latter to a size corresponding to 18 wires to the inch mesh. However, screening prepared in this manner interferes with ventilation to a considerably greater extent than does screening in which the proper aperture area is obtained by using a greater number of finer wires.

MOSQUITO NETS

Mosquito netting or bars are employed for individual protection against mosquitoes and their effectiveness in this respect depends upon the care exercised by the individual. They are utilized principally where troops are sleeping in tents or in poorly screened buildings. The degree of protection which can be attained by the use of mosquito bars is largely a question of discipline. Troops, in general, object to sleeping under mosquito bars and will not use them in the proper manner unless suitable orders are enforced by unit commanders.

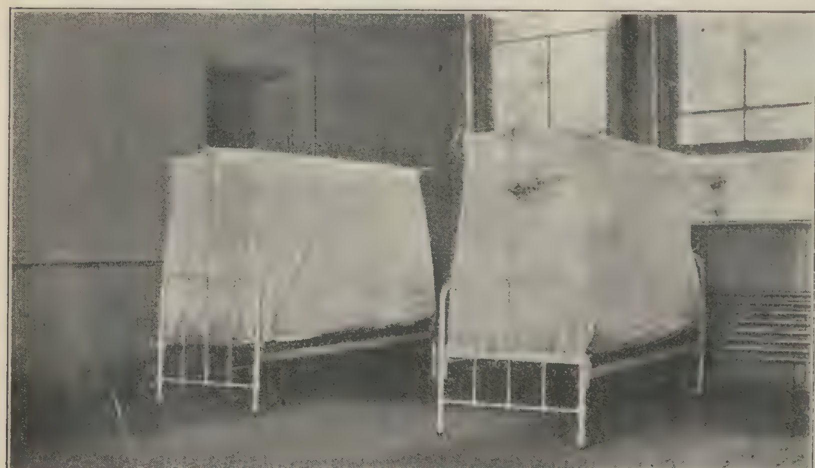


FIG. No. 295. One method of using mosquito bars.

Mosquito bars should be so adjusted that no part of the netting will touch the sleeper and so that the lower edges of the netting are tucked in under the bedding completely around the bed. If the netting touches the bare skin of the occupant of the bed, mosquitoes will be able to bite through the spaces between the threads. If the netting is not tucked in under the bedding upon which the sleeper is lying, mosquitoes will gain entrance between the bedding and the netting. The mosquito net may be made and installed so that the lower edges reach and lie upon the floor.

A mosquito bar frame should be provided for beds and cots, while in the case of shelter tents the netting should conform to the shape of the interior of the tent and be suspended from the tent.

During the day all mosquito bars should be rolled up to prevent mosquitoes from hiding within the folds. When put in place at night, the interior of the net should be searched for mosquitoes. All nets should be inspected at regular intervals for tears, holes and broken threads.

During dusk and the early hours of the night, Anopheles and Culex bite freely in the open. Men on guard and others whose duties require them to remain out of doors in localities where infected Anopheles mosquitoes are prevalent should be provided with head nets and gloves.

ANTI-MOSQUITO CAMPAIGNS

Adequate and effective control of mosquitoes can be obtained and maintained only when the control measures as a whole are executed in accordance with a definite plan. This is true regardless of the extent of the breeding or the simplicity or complexity of the problem presented. Effective control cannot be gained by sporadic efforts, and inadequately planned measures will result in a relatively excessive expenditure of labor and money.

In a given locality, a mosquito-borne disease is, as a rule, transmitted by not more than one or two species. Consequently, the control of the disease will require the control of the disease transmitting species only, although several other genera or species may be present. Thus, for example, while malaria is transmitted by many species of Anopheles, usually not more than one

or two of the species breeding in any one locality are incriminated, although other species of Anopheles and other genera may be present and even more prevalent than the malaria transmitting species. In the United States *Aedes egypti* is the sole transmitting agent of dengue, but other species of Aedes, as well as Culex and Anopheles, may be and frequently are prevalent in the same general locality.

Usually, the primary objective of an anti-mosquito campaign is the control of disease transmitting species. The control of those species which cause discomfort only is ordinarily of secondary importance, but in localities where such insects are very numerous it may be the principal and possibly the only purpose of the control measures.

However, from the viewpoint of disease control, the control measures should be directed primarily and exclusively against the known vectors of the disease concerned. Under these circumstances, an attempt to control all the mosquitoes breeding in the locality will probably produce a dispersion of effort resulting not only in wastage of time, labor and money, but also in failure to attain control of the species transmitting the disease.

In determining upon the control procedures which are feasible and practicable in a given situation, consideration must be given to the bionomics of the species concerned, the nature and prevalence of the disease which is being or might be transmitted, the military situation, the facilities available for control work and the character of the conditions which are to be controlled.

Mosquito surveys. Mosquito surveys are conducted for the purpose of determining the most feasible, and usually the quickest and least expensive procedures for controlling the disease transmitting species in the area under consideration.

Normally, the most important features of a mosquito survey are the identification of the species involved, study of the relative density and importance of each species, and the location of the breeding places of the species, or of each species if there is more than one present. It is usually essential that the species of mosquito concerned be determined, and this phase of the survey is of special importance if Anopheles are to be controlled when there are two or more species breeding in the vicinity.

In making a mosquito survey and deciding upon the control measures to be instituted, consideration must be given to

the degree of protection required or obtainable and the funds and facilities available for mosquito control purposes. In war, it may be that the mission of the troops or the exigencies of the military situation will be such that only partial control will be required or obtainable. In concentration or rest areas, the lack of time and facilities, or even enemy activities, may render it inexpedient to attempt to obtain more than partial control of a varying degree. On the other hand, the conditions at fixed installations during peace, or in the zone of the interior or communications zone during war, are usually such that the disease bearing mosquitoes can be adequately controlled.

Determination of species and prevalence. The species of mosquitoes present in a locality is determined either by identification of captured adults or of the larval forms (page 897).

The determination of species prevalence is largely a matter of estimations based on the number of insects observed or captured. Wide variations in prevalence between species are easily determined, but minor differences may not become apparent during the course of an ordinary mosquito survey.

In capturing specimens for species identification, or in estimating species prevalence by observation, due consideration must be given to the habits and characteristics of the insects concerned. Adults must be sought in their characteristic hiding places or during their normal hours of activity. Typical breeding places should be searched for larval forms.

If a large area is to be surveyed, it may be advisable to establish catching stations for the capture of adult insects. The absolute number and variations in the number of insects collected at the catching stations at regular intervals will provide a basis for estimating species prevalence and determining the effect of control measures. These stations may be stables or houses in the vicinity of breeding places. Stables serve as very satisfactory catching stations for Anopheles. Inhabited buildings are more suitable places for catching *Aedes egypti* and Culex.

Location of breeding places. A thorough knowledge of the breeding habits of the species concerned is essential for success in locating breeding places. The water collections which are actually serving as breeding places at the time of the survey should be definitely located. Not infrequently, water which ap-

pears to constitute a typical breeding place will contain no developmental forms, while prolific breeding may occur in other, but apparently quite similar, collections. Further, certain species may utilize for breeding places collections of water which differ greatly from those in which they would breed by preference were they available.

In the course of the ordinary mosquito survey, all collections of water which could possibly serve as breeding places are searched for larvae and pupae by dipping or by direct examination (page 903). If it is known that only one species of the genus involved is breeding in the area concerned, generic identification of the larval or pupal forms will suffice to indicate the breeding places of that species. Otherwise, it will be necessary to make species identification of the captured larvae.

Method of conducting a mosquito survey. In order to avoid duplication of work or neglect of important features, a mosquito survey should be conducted systematically and in accordance with a preconceived plan. The following summary presents the points that are usually considered in a mosquito survey. It is not probable that all the features mentioned will be present in any one situation, while in some instances it will be necessary to secure data not listed in this summary.

a. Prevailing species. The genus and species of the mosquitoes present in the locality should be determined by examination of captured adults. Special attention should be given to geographical variations in density of the different species, especially those known to be capable of transmitting disease or of causing discomfort.

b. Location of breeding places. All existing and potential breeding places should be investigated, including swamps, seepage areas, marshes, ponds, streams, ditches, artificial water containers, and incidental collections of water. Places in which storm water would collect should also be studied.

c. Dispersion of adult mosquitoes. The relation of inhabited buildings or stables to existing or potential breeding places should be investigated. The dispersion of adults and their local prevalence within and outside of the surveyed area may be determined by routine collections made at catching stations.

d. Nature of terrain. The nature of the vegetation and its probable influence on breeding and the effectiveness of control measures should be studied with reference to such features as brush, high grass, trees, aquatic plants and crops of various kinds.

The extent and character of the natural drainage should be considered, especially with regard to the removal of water from low areas or the formation of pools or puddles of standing water. The nature of the top soil and subsoil should be determined with regard to its effect on drainage.

If the area is large, the presence of roads and their condition may be of importance in the execution of control measures, and should, under these circumstances, be investigated during the course of the survey.

e. Climatic conditions. The amount of rainfall, variations in temperature and humidity, and the velocity and direction of the prevailing winds should be determined.

f. Facilities for control work. The facilities which will be required for the prosecution of control measures should be considered in connection with the results of the survey. These include funds, the quantity and character of the labor, and the kind and amount of equipment and material.

g. The disease situation. Mosquito control measures may be required to prevent the occurrence of disease or to eradicate or control an existing infection. The nature and prevalence of a mosquito-borne disease may influence greatly the character of the control measures instituted and should therefore be investigated as a part of the mosquito survey.

The control of mosquitoes which do not transmit disease but do cause discomfort may be the sole or a partial objective of the anti-mosquito campaign. If so, the genera or species causing discomfort should be studied in the same manner as those which transmit disease.

h. The military situation. Troop movements, training activities or military operations may modify or may determine the kind of control measures which can be employed and, consequently, should be considered as a part of the mosquito survey.

Records and maps. A written record should always be made of the results of a mosquito survey, but it may vary in scope from brief field notes to a voluminous report. If the area is large, a

map should be made showing the features which will be of importance in the control of mosquitoes. A mosquito survey map may include the following points:

a. Boundaries of the area and roads.

b. Location and character of existing and potential breeding places of the different genera and species.

c. Natural drainage, depressions, low areas and slopes.

d. Inhabited buildings and stables.

e. Kind of vegetation.

f. Type of terrain adjacent to but beyond the borders of the surveyed area, such as swamps, marshes, or woods.

In addition to the above features it may be desirable to indicate by means of a sketch or map the location and kind of ditches that have been or should be installed to drain breeding places.

CHAPTER XXII.

CONTROL OF LICE

Human lice are vectors of typhus fever, trench fever and relapsing fever. Furthermore, and aside from the dangers of disease transmission, infestation with lice has an adverse effect on the physical fitness of troops. Heavy infestation, with the consequent irritation due to the bites of the lice, loss of sleep and psychological depression, constitutes a serious menace to the health of the individual soldier, while the presence of lice in a command, even though the infestation is slight, will result in impairment of morale. Consequently, any infestation with lice, however slight it may be, necessitates the initiation and employment of control measures.

Responsibility for control measures. Organization commanders are responsible for the control of lice, in so far as the prevention of conditions which promote the spread of lice through a command is concerned. An organization commander is also responsible for the execution of disinfestation (*delousing*) measures where such measures apply only to the one organization. In camps and stations, or in large commands where the troops from a number of organizations are to be disinfested, the Quartermaster Corps is, normally, responsible for the actual operation of apparatus used for disinfestation purposes.

The Medical Department is responsible for investigating and making recommendations relative to the control of lice and louse-borne diseases among the troops. The scope of Medical Department activities in this respect includes the investigation of environmental factors which would favor the introduction, spread or maintenance of infestation among the troops, and the technical supervision of disinfestation measures.

Classification of lice. Lice belong to class Insecta, and those which infest man belong to the order Anoplura (Siphunculata), family Pediculidae, and genera *Pediculus* and *Phthirius*. All members of the order Anoplura are blood sucking insects, while the louse-like members of the order Mallophaga (biting lice, bird lice) do not suck blood but feed on the epidermis or hair of mammals or the feathers of birds.

Various species of lice infest mammals, but each species is parasitic on its particular animal host and is not found in nature on any other mammal. Thus, for example, dog lice infest only dogs and human lice will suck blood only from man.

The species which infest man are *Pediculus humanus* belonging to the genus *Pediculus*, and *Phthirius pubis*, a species of the genus *Phthirius*. There are two varieties of the species *P. humanus* which are known as *P. humanus corporis* and *P. humanus capitis*. *P. humanus corporis* and *P. humanus capitis* are classified by some authorities as two distinct species, rather than as varieties of the one species.

Pediculus humanus corporis is frequently and usually called the body louse. It is also known as the "clothes louse," "gray back" or "cootie." *Pediculus humanus capitis* is usually called the head louse and *Phthirius pubis* is commonly known as the crab louse.

HABITS AND CHARACTERISTICS OF LICE

Lice develop by incomplete metamorphosis, that is, there are only three stages of development—the egg stage, the nymphal or larval stage, and the adult stage.

The egg stage. The eggs are deposited on the hair of the body or head or on the fibers of the clothing to which they are attached by a cement-like substance excreted by the female.

The eggs of *P. humanus corporis*, or body louse, are usually attached to the fibers of the clothing. However, eggs may be found attached to the hairs of the body, particularly on the chest and in the axillae.

The eggs of *P. humanus corporis* are translucent when newly deposited but soon become opaque and yellowish in color. They are ovoid in shape and about one mm. in length. The egg hatches in about eight days at a temperature of from 86°F. to

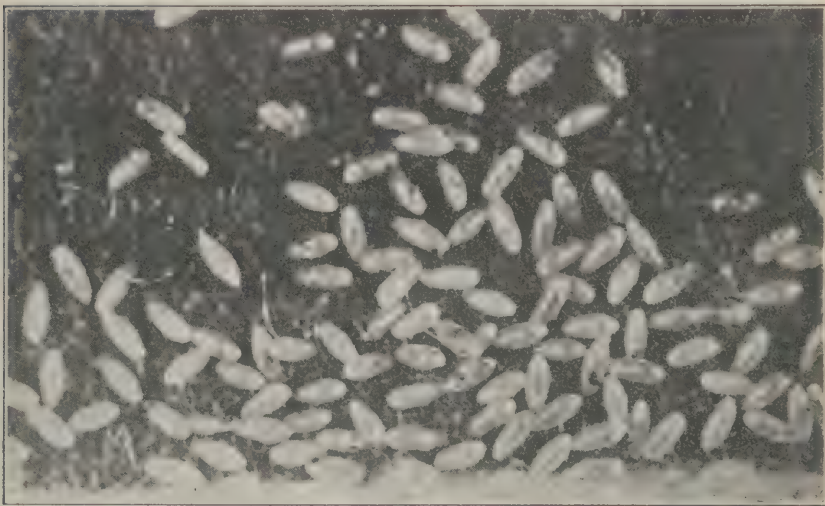


FIG. No. 296. Eggs of *Pediculus humanus corporis.* (Courtesy of the Army Medical Museum).

90° F., which is the usual temperature in the clothing on the body. At a lower temperature, the incubation period may be greatly prolonged, probably for several weeks. The egg is operculate and the larva escapes from the egg by pushing away the operculum (Figures No. 296 and 297).

The egg stage of *P. humanus capitis*, or head louse, is similar in every respect to the egg stage of the body louse, except that the eggs are normally attached to the hairs of the head. They may, however, be found on the hair on other parts of the body.

The eggs of *Phthirius pubis* are as a rule attached to the hairs of the pubic region, but may be found on the hairs of the axilla and other parts of the body. They differ from the eggs of *P. humanus* in that the operculum is slightly more conical and a larger quantity of cement is deposited. Otherwise, the egg stage is similar to that of *P. humanus*.

The larval stage. The larval form of *P. humanus* is similar to the adult, except for certain minor anatomical features and difference in size. The larva as it emerges from the egg is about the size of a common pinhead and is white in color. It begins to feed at once and will succumb within twenty-four hours if unable to obtain blood.

FIG. No. 297. Empty egg shells of *Pediculus humanus corporis* showing opercula. (Courtesy of the Army Medical Museum).

The larval form moults three times at about three day intervals and at the third moult the insect emerges as a sexually mature adult. The second or third stage larva is also known as **a nymph.**

If the infested clothing is worn constantly, seventeen or eighteen days are required for development from the time the egg is deposited until the adult form emerges. The developmental period may, however, be prolonged if the immature forms are subjected to lower temperatures, as, for example, when the clothing is removed at night.

The larvae of *Phthirius pubis* are similar to those of *P. humanus*, except that they do not wander but attach themselves to the base of the hairs and tend to feed from the same spot.

The adult form. The adult louse begins to lay eggs within a day after emergence from the larval stage. The eggs are laid at the rate of from five to ten per day. Under suitable conditions with regard to food supply and temperature, the female louse will live and continue to lay eggs for about 30 days.

P. humanus corporis tend to seek out and frequent that part of the clothing which is in close contact with the surface of the

body. They also tend to congregate in seams of the clothing or where the cloth is doubled. Consequently, the adult insects and their eggs are found in the greatest numbers on the collars of shirts, in cloth over the shoulders, and most frequently in the clothes around the waist and in the crotch of the trousers. While *P. humanus corporis* prefer woolen or other rough cloth, they will live and deposit their eggs on the fibers of smooth cloth, such as silk.

FIG. No. 298. *Pediculus humanus corporis* (body louse). Left—male. Right—female. (Courtesy of the Army Medical Museum).

Lice are voracious feeders and will take blood several times a day. Normally, the body louse clings to the clothing while feeding and for this reason feeds most frequently when the host is quiet or asleep. During the act of biting, the insect injects salivary fluid into the wound to prevent clotting of the blood. Defecation occurs frequently during feeding and the excreta is passed onto the skin or clothes of the host.

The bite of the louse causes irritation and itching which, in turn, results in vigorous scratching and rubbing by the host. Lice may be crushed on the skin and scratching and rubbing of the bitten area may force the excreta and the body fluids

of the crushed insect into or through the bite wound or abrasions of the skin. Frequently, scratch marks or abraded areas are pathognomonic of infestation with lice.

FIG. No. 299. *Phthirius pubis* (crab louse). (Courtesy of the Army Medical Museum).

The habits and characteristics of the adult head louse differ in no essential respect from those of the body louse, except as they may be modified by the fact that, normally, the head louse lives in the hair on the head rather than in the clothes.

The adult *Phthirius pubis,* or crab louse, usually infests the genital and inguinal regions, but may be found on other parts of the body. By means of powerful claws it grasps two approximated hairs and changes position but rarely, and then moves only for short distances. Otherwise, the habits and characteristics of *Phthirius pubis* are much the same as those of body and head lice.

LOUSE TRANSMISSION

The spread of lice from person to person is analogous in many respects to the spread of an infectious disease which is transmitted by direct or indirect contact. The primary source of infestation is always an infested individual and the lice are transferred from the infested person to another person by direct contact, or by indirect contact through the medium of an inanimate object.

Lice may migrate from person to person where contact between individuals is direct or where there is close crowding, particularly during sleep, or they may be shaken from the clothing or blankets of one person onto those of another. Body lice are sensitive to a temperature above that of the normal human skin and body, and a temperature of 100°F. or more will cause them to migrate and seek another host. They will also leave the body and clothing of the dead in search of a blood supply.

Owing to the fact that the egg stage of the body louse may be protracted over a period of from eight days to several weeks, infestation is frequently transferred by the exchange of blankets and clothing which are infested with lice eggs.

Pediculus humanus will die of starvation if separated from its host and thus deprived of human blood. The length of time which adult lice can live without blood depends to a considerable degree on the temperature. At 68°F. lice may survive without food for a week. At a temperature of 40°F. they may live for as long as ten days. Death from starvation will occur in two days at a temperature of 80°F. and in about 12 hours at a temperature of 104°F. *Phthirius pubis* will die in about two days if separated from its human host.

When buildings, rooms, railway cars or dugouts are occupied by infested troops, adult or larval lice may accidentally find their way into dust, straw or other debris and remain after the departure of the troops. However, owing to the lack of a food supply, such places do not remain infested for longer than one week, or at the most eight or ten days, and are not usually, in any event, an important factor in the transmission of lice among troops.

Phthirius pubis, or crab louse, is ordinarily transferred from person to person by direct contact during sexual intercourse. To a lesser extent, infestation with crab lice may be effected through the medium of latrine seats, blankets or clothing. The tendency of the adult to cling firmly to two hairs prevents its transfer to another person unless both hairs become detached, and, as a rule, crab lice are transferred in the egg stage. The hairs to which the eggs are attached are broken off and with the attached eggs become entangled in the hairs on the body of another person.

CONTROL MEASURES

In order to be effective, measures for the control of lice must accomplish complete disinfestation of both the individual and the unit to which the infested man or troops belong. Every piece of clothing belonging to the infested individual and every man belonging to an infested unit must be disinfested. Otherwise, a source of infestation will remain from which lice will spread and produce reinfestation, for if even a single impregnated female louse escapes destruction by delousing measures, she will probably serve as a source of reinfestation of the individual and the unit.

Methods of disinfesting. Infested articles can be disinfested by heat, chemicals or by storage. If a louse control measure is to be effective in preventing reinfestation, it must destroy the eggs as well as the larval and adult forms and the effectiveness of any delousing method or procedure is determined by its effect on the eggs. Moreover, any method which will kill the eggs will, as a rule, also kill the larvae and adults. Further, in the presence of any louse-borne disease, the disinfesting agent should also be a disinfectant and destroy the causative organism of the disease.

Heat. Heat is the most practicable and, generally, the most efficient disinfesting agent. Lice and their eggs are killed in one minute when subjected to dry heat at a temperature of 155°F., or in five minutes at a temperature of 131°F. Immersion in boiling water for 30 seconds will kill both lice and their eggs.

Either moist or dry heat may be used. Ordinarily, disinfestation by steam is the most practical method, although dry heat, and more rarely boiling water, may be used. Steam causes but little shrinkage of woolen cloth, but, unless the clothing is carefully handled, it will produce many wrinkles and an unsightly appearance. Immersion in hot water will cause marked shrinkage of woolen goods. Articles made of leather, felt or webbing are seriously damaged by exposure to either steam or hot water.

Dry heat does not cause shrinkage or wrinkling, but tends to damage the fabric of woolen cloth, especially if the temperature used is sufficient to disinfect as well as disinfest. Dry heat will not injure leather, felt or webbing.

The appliances used to apply heat for disinfestation purposes vary in type from simple, improvised company devices, such as the serbian barrel or hot air boxes, to elaborate steam sterilizers or hot air chambers.

FIG. No. 300. Eggs of *P. humanus corporis* which have been killed by steam. Note shrunken and wrinkled appearance of egg shells. (Courtesy of the Army Medical Museum).

Application of lice control measures. All lice control measures necessarily deal ultimately with the individual soldier and therefore administrative factors play an important role. During peace, it is seldom that more than a few men become louse infested. Under these conditions, disinfestation is usually a company function and may be accomplished by means of such apparatus as the serbian barrel (page 972), or a post laundry may be utilized. In open warfare, disinfestation is likewise, as a rule, a function of the company or battalion and serbian barrels or other improvised devices or procedures are ordinarily employed for this purpose. At mobilization and training camps in the zone of the interior, at ports of embarkation or debarkation, or in any similar situation where large numbers of troops are assembled, disinfestation is usually a function of some one agency operating directly under

camp or post headquarters and is accomplished by means of delousing plants.

In a theater of operations, disinfestation is usually carried out by means of portable or mobile disinfestors, or improvised devices, rather than by permanent delousing plant installations. In divisional concentration, rest or training areas in a theater of operations, disinfestation may be a divisional activity and directed by division headquarters. One or more temporary delousing plants may be installed for the purpose of disinfesting all the troops of the division and such a plant may be operated by personnel of the division or by a clothing and bath unit (page 971).

Fixed installations in a communications zone may be equipped with steam sterilizers or hot air disinfestors. Small commands or detached bodies of troops ordinarily utilize improvised devices, such as the serbian barrel (page 972), or hot air boxes (page 976) for disinfestation. Storage may prove to be the most suitable method of disinfestation in any situation.

Delousing plants. The usual delousing plant consists, basically, of steam or hot air disinfestors and facilities for bathing, for inspecting the troops for lice and for the re-issue of disinfested clothing or blankets. Usually, a delousing plant also includes a barber shop where the hair may be trimmed. A delousing plant is a quartermaster agency and is normally operated by the Quartermaster Corps. However, as disinfestation is a technical procedure and the inspection of the troops is an important phase of the operation of the plant, the Medical Department is intimately concerned, from a technical viewpoint, with the operation of every delousing plant.

The capacity of a delousing plant may vary from as few as 200 to as many as several thousand men per day, according to the requirements of the situation. The smaller plants may be operated as adjuncts to a camp laundry.

Camp delousing plants are, as a rule, housed in permanent or semi-permanent buildings. The disinfesting equipment usually consists of stationary or portable steam sterilizers. Hot air chambers or rooms may be used for disinfestation by dry heat but have not proven as satisfactory as the steam sterilizers. The interior arrangement of the plant depends somewhat on its

capacity, the shape of the building and the type of equipment used. However, the following general principles should be observed in the installation of a delousing plant:

a. There must be no mixing of clean and infested men or of clean and infested clothing.

b. The plant should be definitely divided into two parts —a clean side and an infested side—which are connected only through the shower baths for the men and through the disinfestors for the clothing and blankets.

c. The floor should be made of concrete and provided with sufficient slope and drainage outlets to permit rapid and adequate cleaning by flushing.

d. The entire building should be well lighted by natural lighting, but special care should be taken that the rooms or parts of the building used for the physical inspection or the inspection of clothing are adequately lighted.

e. Separate toilet facilities should be provided for infested men and for clean men.

f. Means should be provided for heating the building to a suitable temperature.

g. The minimum divisions of a large delousing plant should be:

1. A receiving room large enough to care for an excess number of men if troops are sent to the plant too rapidly.

2. A disrobing room.

3. A checking room where shoes, belts and other articles that may not require disinfestation and valuables may be checked.

4. A shower bath room.

5. A disinfestor room.

6. A dressing room.

7. A barber shop.

8. A physical inspection room.

In the case of smaller plants, some of the above divisions may be combined.

Steam sterilizers. The steam sterilizers are of various designs and capacities and are usually of the pressure type.

The ordinary pressure sterilizer employed for disinfestation of clothing consists of a horizontal steam chamber around which there is an outer jacket. The larger stationary sterilizers usually have a vacuum door at each end, while the portable type has a vacuum door at only one end. Steam for the larger stationary sterilizers is furnished through pipes from boilers which are not directly connected with the sterilizer. With the portable sterilizers and some of the smaller stationary types, the boiler and the steam chamber are assembled as a unit.

FIG. No. 301. Battery of stationary steam pressure sterilizers (disinfestors) in delousing plant.

The sterilizer is equipped with a loading car mounted on a removable extension track by means of which the clothing is placed in and removed from the steam chamber. The larger stationary sterilizers are usually so installed that one end of the sterilizer with its vacuum door is in a room on the infested side of the plant, while the other end, from which a corresponding vacuum door opens, is in another room on the clean side. The disinfested clothing can then be removed from the

sterilizer without danger of contact with infested articles and consequent reinfestation.

In the operation of the pressure steam sterilizer, a positive steam pressure is maintained in the outer jacket in order to heat the apparatus. The loading car containing the material to be disinfested is run into the steam chamber, the extension tracks are removed, and the vacuum door closed. A vacuum of from 10 to 15 inches is then created in the steam chamber, after which steam is turned into the steam chamber until a positive pressure of about 15 pounds is attained. Steam pressure is held at from 12 to 15 pounds for about 20 minutes. At the end of this time the steam is released and a vacuum of 10 to 15 inches is again produced for the purpose of drying the clothes. The drying vacuum is usually held for from five to ten minutes and then broken by the admission of air into the steam chamber through a valve. The disinfested material is dry when removed, or if slightly moist, it will dry in a few moments after removal from the steam chamber.

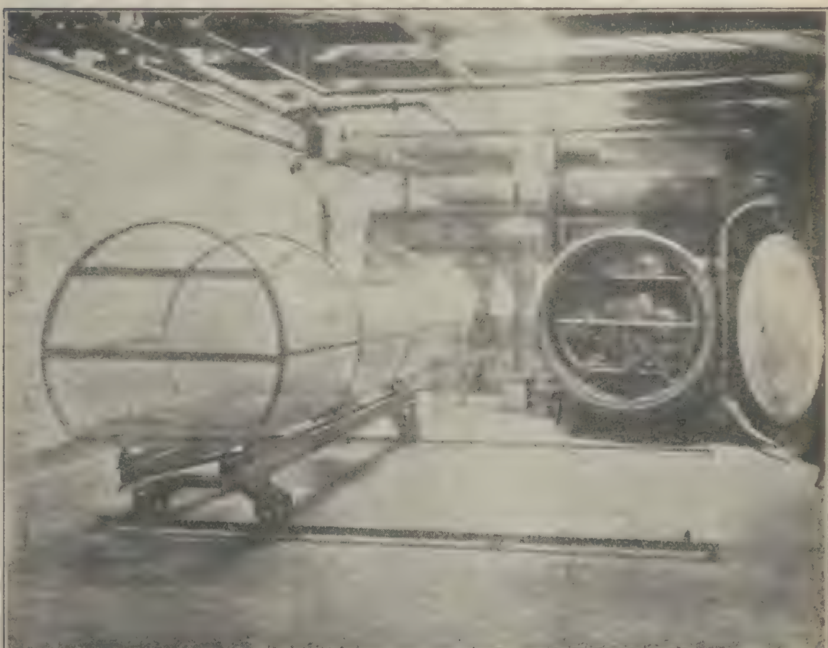


FIG. No. 302. Stationary steam pressure sterilizer (disinfestor) in large delousing plant.

The preliminary vacuum and subsequent positive pressure serve to remove the air from the clothing and facilitate the penetration of the steam. However, in order to insure complete penetration and the destruction of all eggs, the material should be placed loosely and not packed into the car. Bags may be used to hold the clothing of the individual soldier. A bag made of netting or of light loose woven cloth should be used where practicable, rather than a standard barracks bag. If bags are not used, clothing and blankets should be folded and laid loosely in the car. Clothing may be hung from hooks fastened to a rod at the top of the car. This latter method will also minimize wrinkling.

Current steam sterilizers, or disinfestors, of the Thresh type may be used. In the Thresh disinfestor, the steam flows through the steam chamber displacing the air in the clothing. No preliminary or drying vacuum is created and the steam is not under pressure. The condensation of water in the steam chamber is prevented by pre-heating the steam to 212°F.

A period of from 20 to 30 minutes is required for disinfestation, after which the steam is turned off and the disinfested material dried by passing a current of hot air through the steam chamber. Current steam disinfestors require less steam and less mechanical skill to operate than the pressure type, but they are also less efficient as disinfestors.

Hot air disinfestors. Hot air disinfestors, as installed in a delousing plant, consist of built in hot air chambers or ovens. They are usually large enough to hold a number of long racks from which the clothing is suspended from hooks. Steam heat is ordinarily used, with pipe heating units within the disinfesting chambers. The chamber walls are insulated. Fans are used to circulate the air and thus maintain a uniform temperature throughout the chamber.

The use of hot air as a disinfesting agent is advantageous as compared with steam, in that dry heat at a temperature lethal for lice and lice eggs will not injure leather, metal or webbing. Also dry heat does not cause wrinkling of woolen cloth.

The principal disadvantage of a hot air disinfestor is the difficulty experienced in securing penetration of the heat into spaces between the folds of woolen cloth. This difficulty can be obviated only by increasing the temperature to a degree

which will injure the fabric of the cloth, by lengthening the time of exposure, or by spreading the material so that all portions are exposed directly to the air. As time is frequently an important factor in disinfestation work, the latter two methods are not always practicable. A further disadvantage is that hot air, at temperatures which will kill lice and their eggs, is not an efficient disinfectant and cannot be depended upon to destroy the causative agents of louse-borne diseases.

Generally, steam sterilizers are more satisfactory for use in delousing plants than hot air disinfestors.

Operation of delousing plants. If any considerable number of troops are to be disinfested, a definite schedule should be employed by which detachments, platoons, companies or battalions report at the delousing plant at a given time. The troops bring to the plant all their clothing, together with their blankets and any other articles which could be infested with lice. In hospitals, permanent camps, stations or other situations where the troops are provided with mattresses, the mattresses must also be disinfested. If bedsacks are used, the straw should be burned and the bedsack disinfested. If Gold Medal cots are used, the cots should be disinfested, either by steam or with a cresol solution.

The operation of delousing plants varies in detail according to the arrangement and equipment of the plant and the type of personnel available for its operation. However, the following general procedures are employed in the operation of most plants.

Immediately on entering the delousing plant the troops disrobe and each man places in his barracks bag all articles which can be disinfested by steam, including the uniform, shirt, underclothing, socks, identification tag and tape, blankets and such other clothing or cloth articles as he may have in his possession. Mesh or netting bags may be furnished in lieu of barracks bags and are more satisfactory. The bag is given to an attendant who marks it with a numbered tag and gives a duplicate tag to the owner of the bag. The bags are sent to the disinfestor while the articles which cannot be disinfested by steam, such as shoes, leather belts or leggings, may be carried by the individual or they may be checked in a check room to be returned to the owner when he receives his disinfested equipment. Shoes, leather belts, leggings and felt

hats do not ordinarily require disinfestation. If infested, they should be disinfested with dry heat or a five per cent cresol solution.

From the disrobing room the troops may pass immediately before examiners who examine them for pediculosis and skin diseases. Usually, however, the inspection for infestation can be more satisfactorily conducted after bathing.

FIG. No. 303. Shower bath room of a large delousing plant.

The examiners usually are, and should be, medical officers, but especially trained Medical Department noncommissioned officers may be employed as examiners. The hair on all parts of the body, and especially in the axillary, pubic and inguinal regions, should be carefully and thoroughly examined for eggs (nits). The scalp should also be inspected for head lice. The skin should be examined for scratch marks or reddened or irritated areas indicative of irritation due to louse bites. Evidence of louse bites is most frequently found in the axillae, on the neck under the collar, on the shoulders, especially over the clavicles, around the waist, and in the perineal, pubic and inguinal regions. Every man should also be carefully examined for evidence of scabies.

Either before or after the physical examination, the troops pass to the shower bath room where each man is provided with soap and a towel and required to take a shower bath. The bath should be taken under the supervision of a noncommissioned officer, and the bather should be required to scrub thoroughly all parts of the body.

FIG. No. 304. Portable steam disinfestor in operation.

Bathing with soap and water will not, in many instances, destroy all the eggs attached to the hairs of the body. Where infestation is evidenced, either by the presence of eggs on the hairs or by indications of louse bites, the hair in the axillary, pubic and inguinal regions and, if necessary, on the chest should be shaved or clipped. If shaving or clipping is not practicable, these parts of the body surface should be thoroughly scrubbed with vinegar, kerosene or gasoline. Where a considerable pro-

portion of the troops examined are infested, every man should be disinfested in this manner. If only a few men are found to be infested, only those showing evidence of infestation need be given this treatment. If head lice are found, appropriate treatment should also be given at this time (page 980).

After disinfestation, the troops pass to the clean side of the plant where they receive their clothing, which has been disinfested while they were being examined and bathed. Here also they receive the articles which were checked in the disrobing room. After dressing, those requiring hair cuts should be sent to the barber shop, if one is operated in connection with the delousing plant. Clean, serviceable clothing may be issued to replace unserviceable or soiled articles.

FIG. No. 305. Portable steam disinfestor. (Note loading car and tracks).

Mobile disinfestors. Mobile, or portable steam disinfestors are mounted on wheels, usually on a four wheeled trailer, and can be moved from place to place as required. The portable steam pressure disinfestor is more commonly used, although a portable current steam disinfestor has also been devised.

The portable steam pressure disinfestor is similar in construction and operation to the pressure sterilizer described above for delousing plants (Fig. No. 304).

The weight of the portable steam pressure disinfestor restricts its movement to areas where good roads are available. It is used principally in temporary camps, rest areas, hospitals, or other situations where the installation of a permanent delousing plant is impracticable.

The clothing and bath unit. The clothing and bath unit is a Quartermaster Corps organization. It is equipped with portable steam pressure disinfestors and portable shower baths.

Clothing and bath units normally function in rest areas, concentration camps and other temporary situations in the theater of operations. They may establish and operate delousing plants of a more or less permanent nature.

Disinfestation by improvised devices and procedures. In situations where delousing plants, the services of a clothing and bath unit, or portable disinfestors are not available, improvised disinfesting devices and procedures must be utilized to control infestation. Usually, such situations arise where small bodies of troops are operating in the field, at camps or establishments where the nature of the roads or terrain will not permit movement of the heavy steam disinfestors or the installation of delousing plants, or in the combat zone. Under these conditions, disinfestation is a function of the company or detachment concerned and the company commander is responsible for the disinfestation of his troops.

Disinfestation by means of improvised devices and procedures should always include inspection of the troops by medical officers or specially trained Medical Department enlisted men. Usually, it is desirable to make reinspections to determine the efficiency of disinfestation.

Disinfestors of the serbian barrel type are most commonly used for delousing small quantities of clothes and blankets.

Hot air boxes or cans may be used or clothes and blankets may be deloused by washing in hot water. Chemicals may be employed to destroy lice or repel them. Disinfestation may also be accomplished by storage.

The serbian barrel. The serbian barrel consists of a barrel, or a similar container for the material to be disinfested, below or in the lower part of which there is a receptacle for water and an improvised furnace or fire box.

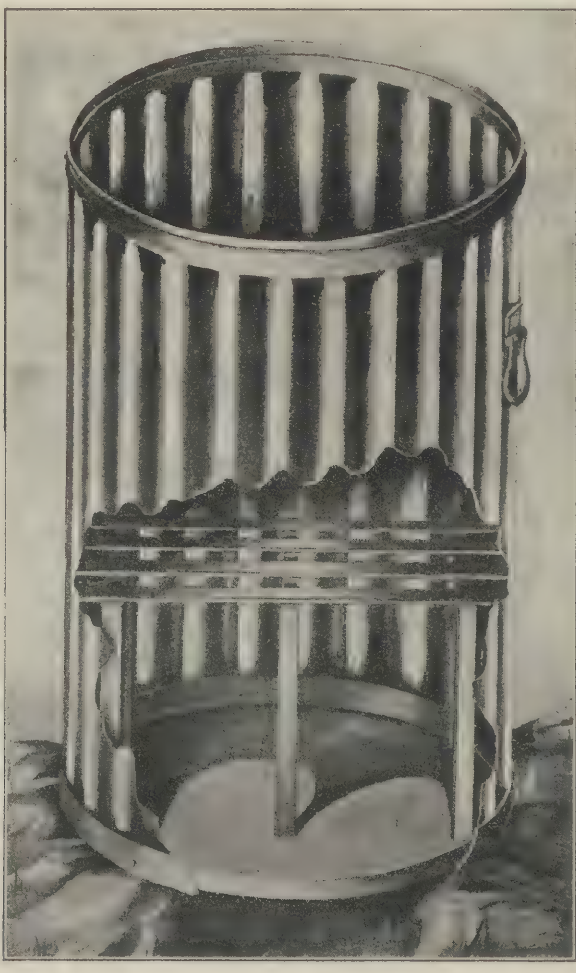


FIG. No. 306. Serbian barrel consisting of galvanized iron can. Wooden rack prevents clothing or blankets from falling into the water below.

The galvanized iron garbage can is usually the most practicable and the most readily available device for use as a serbian barrel. This can, being made of metal, does not require a water receptacle beneath it. Water to a depth of about six inches is placed in the bottom of the can and the can is placed directly over the fire. A wooden grate supported on sticks about one foot in length should be placed in the bottom of the can to hold the clothes above the water (Fig. No. 306). Hooks on which to hang the clothes may be bolted or riveted into the lid, or S-shaped wire hooks may be hung over the edge of the can (Fig. No. 307). The fire box usually consists of a single trench or a cross trench. A brick or concrete fire box or furnace equipped with a smokestack may be used.

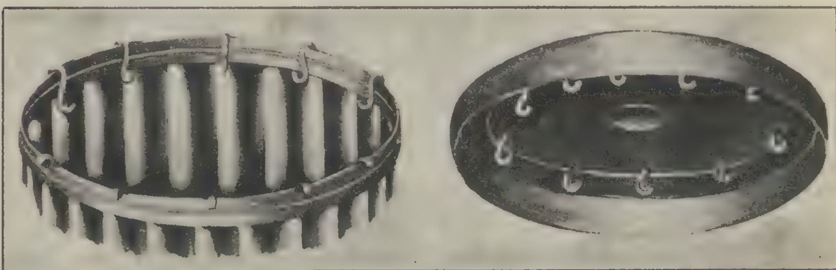


FIG. No. 307. Hooks for suspending material in galvanized iron can used as serbian barrel.

A serbian barrel may be made from an ordinary water tight wooden barrel (Fig. No. 308). The top and bottom of the barrel are removed, or only the top is removed and the bottom is perforated with a number of small holes. The barrel is placed over a water pan or pot in such a manner as to prevent the free escape of steam around the lower edges of the barrel. The water receptacle, supporting the superimposed barrel, is firmly embedded in a clay, brick, stone or concrete base. This base is placed over an improvised furnace, or more commonly over cross trenches (Fig. No. 308) the intersection of which serves as a fire box.

The barrel is equipped with a well fitting, removable lid, in the under surface of which may be inserted a number of hooks to support the clothing (Fig. No. 307). If necessary,

weights consisting of rock, sandbags, brick or pieces of concrete may be laid or fastened on top of the lid to hold it firmly in place.

If the bottom of the barrel is removed, instead of being perforated, a wire or wooden grating should be installed about six inches above the bottom to prevent the contents of the barrel from reaching or falling into the water below.

FIG. No. 308. Serbian barrel made from an ordinary wooden barrel and installed over cross trenches.

An upright rectangular container, without a bottom and with a tight fitting lid, may be constructed of boards and used in lieu of a barrel. The lid and sides should be lined with tin, zinc, tar paper or other material impervious to steam. The sides of the container may be held in place by bolts or hooks so that it can be taken apart for transportation (Fig. No. 309).

The water pans for either the barrel or rectangular containers may be fashioned of light galvanized iron. Iron or tin pans or pots of various sizes and shapes may be used for this purpose, if specially constructed pans are not available.

The serbian barrel is operated by first heating the water to the boiling point, after which the clothes or blankets to be disinfested are placed in the barrel. The different pieces

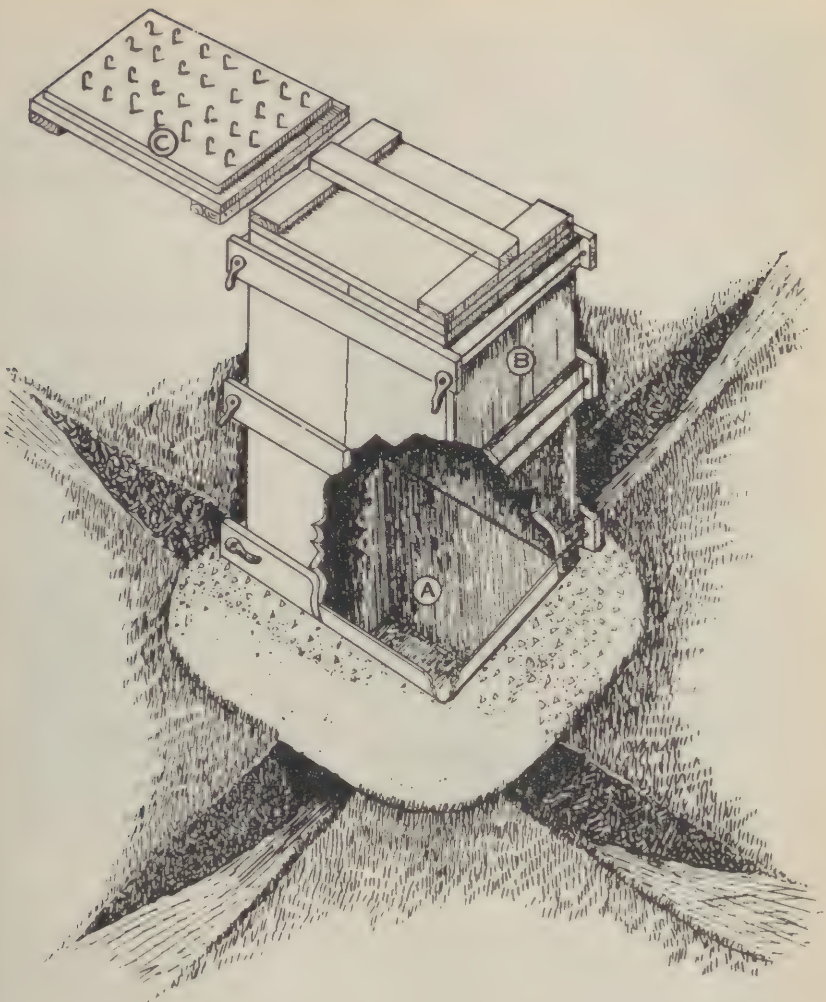


FIG. No. 309. Serbian barrel. A—Water receptacle set in a concrete base. B—Rectangular container so constructed that it can be taken apart for packing. C—Hooks for hanging clothing. (Note iron rods and tail nuts which hold sides together).

should be hung from the hooks or, if the barrel is not equipped with hooks, laid on the grate. They should never be packed into the barrel in such a manner as to prevent circulation of the steam and its penetration into all the material. Care should be taken that the lid fits snugly and it should be weighted if necessary to secure a tight fit. Disinfestation should continue for forty-five minutes after steam begins to

escape around the edges of the top or bottom of the barrel. The water should be kept boiling throughout the disinfestation period. The steam is under practically no increased pressure and the relatively long disinfestation period is necessary in order to insure penetration of the steam into all parts of the material in the barrel, and the consequent destruction of all lice eggs.

FIG. No. 310. Collapsible serbian barrel disinfestor.

Clothing or blankets are wet when removed from a serbian barrel at the end of the disinfestation period. The retained heat will be sufficient to produce complete drying in a short time if the atmosphere is dry. In a humid atmosphere or during wet weather, it may be necessary to dry the disinfested material in drying rooms or by other means.

Improvised hot air disinfestors. Clothing and blankets may be placed in ovens, boxes or cans and subjected to a sufficient degree of dry heat to kill the lice and eggs. If ovens are used, care must be taken to avoid scorching the clothing. Hot air boxes may be constructed on the same principle as a fireless cooker and heated by a piece of metal. The clothing may be placed in a metal can which is in turn placed in another receptacle, such as a large kettle or boiler which contains water.

The boiling water heats the air in the can containing the clothing to a degree which will kill the lice and eggs. In any of these devices it is difficult to obtain penetration of the heat into spaces between folds of the clothing and the clothing should remain in the disinfestor for at least one hour.

Small buildings, rooms or dugouts may be converted into hot air disinfestors by installing heating apparatus which will heat the air to about 160°F. The clothing to be disinfested should be hung loosely and the heated air circulated by means of fans. The clothing should be exposed to the hot air for at least 30 minutes.

Hot irons. Clothing can be partially deloused and the degree of infestation reduced by removing the adult lice by hand and then killing the eggs by ironing the cloth, especially the seams and folds, with a hot iron. An ordinary sad iron, or a piece of iron pipe or scrap iron with a wooden handle attached, may be used for this purpose.

Hot water. Cotton, linen or silk clothing may be disinfested by immersion in boiling water for one minute, or in water having a temperature of 135°F. or more for five minutes. In order to *disinfect* as well as disinfest, the clothing should be subjected to a temperature of at least 160°F. for from fifteen to thirty minutes. Woolen clothing can be disinfested by this process, but considerable shrinkage will occur. Leather, felt or webbed articles are damaged by exposure to hot water.

Storage. Storage of infested clothing will accomplish disinfestation by depriving the lice of a food supply. When denied access to a human host, the adult forms die of starvation within a ten day period and the larval forms will survive for only about twenty-four hours after hatching. However, in order to allow sufficient time for all the eggs to hatch, infested articles should be kept in storage for at least thirty days in cold weather and for not less than three weeks in warm weather.

Not infrequently, storage is a very practical method of disinfesting clothing and blankets in hospitals or camps, provided clean equipment is available for issue and facilities for storage can be obtained. The rooms or buildings used for storage should be dry. Freshly infested articles should not be stored with those which have been in storage for some time. No article should be removed from a storage room

until after all articles in that room have been in storage for at least thirty days.

Chemicals. Chemicals, such as acetic acid (*vinegar*), kerosene, gasoline, cresol, or naphthalene, may be applied as insecticides to the person or clothing of the infested individual. Most of the insecticides when applied to the person will destroy or repel the adult and larval forms but will not kill the eggs. Ten per cent acetic acid (vinegar), pure or a fifty per cent suspension of kerosene or gasoline, will loosen the eggs attached to hairs and facilitate their subsequent removal by rubbing, brushing or combing. Crude naphthalene, or a powder consisting of 96 parts of naphthalene, two parts of creosote and two parts of iodoform (N.C.I. powder), will, when dusted into the seams of the clothing, serve as a louse repellent. A naphthalene paste consisting of four parts of crude naphthalene and one part of soft soap may also be used as a repellent by rubbing it into the clothing.

A five per cent solution of cresol in water is an efficient disinfestant when used for washing articles such as leather shoes and belts, felt hats or web belts, which would be damaged by subjection to steam. Clothing and other articles may be disinfested, with destruction of the eggs as well as the adult and larval forms, by immersion for 30 minutes in a three per cent solution of cresol, if the temperature of the solution is held at about 100°F.

Improvised baths. Bathing is an essential and necessary part of disinfestation of the body. Permanent delousing plants are provided with bathing facilities (page 969). The clothing and bath unit (page 971) is equipped with portable shower baths. Under other conditions, it may be necessary for a unit to improvise bathing facilities.

Improvised bathing equipment may consist of an elevated tank and the necessary piping and shower heads. Usually, the tank is made of wood and is elevated on wooden supports to a height of seven or eight feet. It may have a capacity of from 300 to 2000 gallons or more. The metal tank of the ordinary water cart may be used for this purpose if available. The outlet pipe from the bath tank should extend outward at a height of from six and a half to seven feet. It is usually supported on wooden uprights. Shower heads or faucets are screwed into the pipe. The ordinary company bath should

FIG. No. 311. Improvised shower bath. Water sterilizing bag with rubber tube and shower head attached to one of the faucets.

be provided with a sufficient number of shower heads to permit eight men to bathe at one time.

The tank is usually filled by means of a hand pump, or possibly by a small gasoline pump. The water may be delivered to the bath tank in water carts or tank trucks, or the water may be pumped directly into the tank from a nearby stream or well.

The water sterilizing bag may be utilized as a temporary bath tank for a small number of men (Fig. No. 311). The bag is hung so that the bottom is from six to seven feet above the ground or floor. One of the faucets can be used as an outlet. A rubber tube two to four feet in length may be attached to one of the faucet pipes of the bag and the other end equipped with an improvised shower head or a faucet.

Improvised baths may be housed in a building or tent (Fig. No. 311). Waste water should be disposed of by drainage to some remote place where it will not create a nuisance or into soakage pits or trenches in the vicinity of the bath (page 729).

It is usually impracticable to heat the water for improvised baths. Occasionally, especially in the case of semi-per-

manent installations, it may be feasible to construct a furnace with hot water coils. Hot water should be furnished whenever practicable.

Removal of head lice. The physical examination of troops for lice should include inspection for head lice. Disinfestation can be accomplished by loosening the eggs from the hairs by the thorough application of ten per cent acetic acid (vinegar), followed by shampooing the scalp with hot soapy water containing twenty-five per cent of kerosene to remove the detached eggs and kill the adult and larval forms. After shampooing, the hair should be thoroughly combed and brushed to remove any of the eggs which might not have been carried away by the water. Where practicable, the hair should be clipped short.

CHAPTER XXIII.

CONTROL OF OTHER INSECTS

TICKS, SAND FLIES, FLEAS, BEDBUGS, ROACHES AND ANTS.

TICKS

Ticks are important disease transmitting agents in some parts of the world, but, as compared with mosquitoes and lice, they are of relatively minor importance in the transmission of disease among American troops. In America, ticks transmit Rocky Mountain spotted fever and the relapsing fever of Central and South America. They also transmit tularemia, but are not the common agent by which that disease is transmitted to man.

Ticks require blood as food but no one species is strictly parasitic on any one host. The selection of an animal host by a given species is, in many instances, determined by the availability of the animal in question and the opportunities offered for the ticks to become attached. Ticks are not normally human parasites but bite man only incidentally and following failure to find a more suitable host. Members of the genus *Ornithodorus* infest the habitations of man and, in absence of other sources of blood, attack man to obtain food. These species are, to this extent, parasitic on man.

Classification of ticks. Ticks belong to the class Arachnida, order Acarina, and families Ixodidae and Argasidae. The genera Ornithodorus, Dermacentor, and, possibly, Ixodes, are concerned in the transmission of relapsing fever, Rocky Mountain spotted fever or tularemia. The species most commonly in-

volved are *O. moubata* in Africa and *O. talaje, O. venezuelensis, D. andersoni,* and *D. variabilis* in the Western Hemisphere.

The wood ticks, *Dermacentor andersoni* and *D. occidentalis,* and the dog tick, *D. variabilis,* are the most important ticks found in the United States, in so far as transmission of disease to man is concerned. All of these ticks have been incriminated as insect hosts and transmitting agents of Rocky Mountain fever and tularemia (page 878). *D. andersoni* is found in the Rocky Mountain region generally, and more particularly in Montana, Wyoming, Idaho, and Washington. *D. occidentalis* is the wood tick of the Pacific Coast. *D. variabilis* (dog tick) is widespread in the United States, and is especially prevalent in the midwestern, eastern, and southern regions. *D. variabilis* is also known as the common wood tick of the Eastern United States.

Haemaphysalis - leporis - palustris (*the rabbit tick*) is also concerned in the transmission of the infective agents of Rocky Mountain spotted fever and tularemia from rodent to rodent, especially among rabbits.

O. talaje and *O. venezuelensis* are the transmitting agents of relapsing fever in tropical America.

Recently, evidence has been advanced suggesting that *Ixodes ricinus californicus* is capable of transmitting tularemia. This species is a common tick in the Pacific Coast region. The wood tick and *Ixodes ricinus* have been shown to be the cause of tick paralysis in man and animals (page 881).

FIG. No. 312. *Dermacentor andersoni* (wood tick).

Habits and characteristics. The developmental forms of the tick consist of the egg, larva, nymph and adult. The larval, nymphal and adult forms are blood suckers and do not

take other food. The larvae and nymphs develop by moulting and are similar to the adult in structure and appearance, except that they are smaller and the larva has only six legs while the nymph and adult have eight. The genital pore is also absent in the larval and nymphal forms.

Dermacentor andersoni, D. occidentalis, and *D. variabilis* are three host ticks and will feed on practically any warm blooded animal, including man. The dog tick (*D. variabilis*) is especially prone to attack man. The immature forms are usually found on small animals, such as rodents. Many ticks, in both the immature and mature stages, must necessarily fail to find a host and eventually starve to death. Nevertheless, while development of the immature forms is inhibited by lack of food, ticks can withstand long periods of starvation, especially in the nymphal and adult stages. Adult ticks can live for two years, or longer, without food.

Cold delays the development of the immature forms but extremely cold weather will not kill Dermacentor ticks in any stage, nor will it destroy the virus of Rocky Mountain spotted fever. All forms hibernate over the winter season.

D. andersoni is typical of the genus *Dermacentor.* This species deposits several thousand eggs in a mass on the ground. The egg stage lasts from three to four weeks to several months, depending on the temperature. When the eggs hatch the larval or "seed" ticks emerge and cling to blades of grass or twigs until an opportunity is presented to attach themselves to a warm blooded host. After feeding for from two to four days, the larva drops to the ground where it remains dormant for several weeks. It then moults and becomes a nymph. The nymphal forms seek a warm blooded animal host upon which to feed. After feeding for from four to eight days the nymph drops to the ground where, after a lapse of several weeks, moulting occurs and the adult form emerges. The adult searches for, and becomes attached to a host, where feeding again occurs and copulation takes place. After ten days to two weeks, the gravid female drops to the ground and deposits her eggs and dies.

Ornithodorus moubata, O. talaje and *O. venezuelensis* tend to infest the habitations of man. They feed at night and remain in hiding during the day. Both the nymphal and adult forms will attack and feed on man. They can survive for a long time, possibly for several years, without food.

The eggs of *O. moubata, O. talaje* and *O. venezuelensis* are deposited in small batches in the earth or in cracks and crevices of the building or furniture. Under favorable conditions, the eggs hatch in about two or three weeks.

The larva develops into the nymphal form within the egg. The immature form passes through three or four nymphal stages before reaching the adult form.

Transmission of disease. Ticks are able to transmit the etiological agents of Rocky Mountain spotted fever, relapsing fever and tularemia through the egg stage to their progeny. In the case of relapsing fever, as transmitted by *Ornithodorus,* the adult tick can become infected by biting a person having the disease and not only transmit the infection to another person during its own life, but also transmit it through the bites of succeeding generations of nymphs and adults. *Dermacentor,* being a three host tick, may become infected with the virus of Rocky Mountain spotted fever, or with *B. tularense,* during the larval or nymphal stages and transmit the infection to man during the adult stage, or it may become infected during the larval, nymphal or adult stage of one life cycle and transmit the disease to man by the bites of succeeding generations of larvae, nymphs or adults.

Control of ticks. Control of tick-borne diseases by the eradication of the tick is difficult to achieve, and is, in many instances, impracticable. Native huts infested with *O. moubata, O. talaje* and *O. venezuelensis* should be burned, as the fact that ticks can live for long periods without food renders vacated huts dangerous. A kerosene or cresol insecticide (page 993) may be applied to tick infested floors, walls, ceilings or furniture. It should be applied in the same manner as described under control of bedbugs.

Control of wood ticks and dog ticks must be attained mainly by control of their wild animal hosts. As the larval and nymphal forms feed principally on the smaller animals, such as squirrels, rabbits, prairie dogs or wood chucks, the eradication of these animals from an infested area is an important factor in tick control. The cultivation of arable land and yearly burning of the underbrush on waste or uncultivated ground will reduce the number of animals and destroy some of the ticks. Trapping, poisoning and shooting of wild animals are also effective methods of depriving the tick of its hosts.

Owing to the fact that the adult tick remains on the larger animal hosts for only a short time, dipping of domestic animals for the purpose of freeing them from ticks is not an effective procedure for reducing the prevalence of *D. andersoni.*

In certain regions sheep grazing is a valuable control measure. When ticks attack sheep many of them become entangled in the wool and are unable to escape or obtain a blood meal. The ticks are also killed by the lanolin in the wool. When sheep are grazed over an area they destroy much of the vegetation which would otherwise afford shelter and food for rodents, and thus indirectly deprive ticks of suitable hosts. If sheep are grazed away from inhabited areas into the mountains during the spring months of each year, they will carry many of the ticks away into remote regions where, if they escape from the sheep hosts, they will not have an opportunity to infect man.

A small gnat-like insect, *Ixodiphagus caucurtei*, belonging to the order Hymenoptera, is a natural enemy of *D. andersoni. Ixodiphagus caucurtei* deposits its eggs in the body of the tick, usually in the nymph. The eggs develop inside the tick and destroy it. These insects have been distributed in large numbers in certain regions where Rocky Mountain spotted fever is prevalent for the purpose of parasitizing and destroying the ticks.

Dogs may be freed of ticks by the use of derris root powder, or some one of the commercial preparations containing derris, or rotenone, which is the active principle of derris (page 808). The powder should be dusted into the hair on all parts of the animal where ticks are attached, and allowed to remain. The application of derris powder every three or four days will, to a considerable extent, prevent dogs from becoming infested with ticks.

FLEAS

While the flea is the agent by which plague and endemic typhus are transmitted from infected animals to man, procedures for the control of these diseases are, as a rule, designed to eradicate the infected animal hosts of the fleas, and not primarily for the control of the fleas. Under certain conditions in combatting plague it may be desirable to institute measures for the direct control of fleas but, ordinarily, such measures are employed only where fleas are a pest.

Both the male and the female flea are bloodsucking insects. There are many species of fleas and each species is, to a varying degree, parasitic on some mammalian or avian host. In most instances, however, parasitism is not absolute and blood will be taken from another host when the preferred host is not readily accessible.

The fleas which commonly bite man are those which are normally parasitic on animals closely associated with man, such as the dog, cat and rat. The species which attack man most frequently are *Pulex irritans*, the so called human flea, which is probably normally parasitic on domestic animals, *Ceratophyllus fasciatus*, the common rat flea of North America and Europe, *Ctenocephalides canis*, the dog flea and *Ct. felis*, the cat flea, and *Xenopsylla cheopis*, the rat flea of the Orient. Where species which are parasitic on wild animals have access to man, they too will bite man. Thus, *Hoplopsyllus anomalus* and *Ceratophyllus acutus*, which are normally parasitic on the California ground squirrel, will bite man and are capable of transmitting plague bacilli from the squirrel to man. *Xenopsylla cheopis* is the most important vector of plague bacilli. *Ceratophyllus fasciatus* and *X. cheopis* are the most common vectors of endemic typhus fever

FIG. No. 313. Right—*Pulex irritans*, (human flea) female. Left—*Ctenocephalides felis*, (cat flea) female.

(page 860). The rat fleas, *C. fasciatus* and *X. cheopis* serve as intermediate hosts for the tapeworm *Hymenolepis diminuta* and for the dog tapeworm, *Dipylidium caninum.*

Habits and characteristics. The flea develops by complete metamorphosis. The eggs are deposited in, or fall into the debris and dust of the nest or resting place of the animal host. The length of the egg stage is from two days to a week or more and depends somewhat on the temperature and humidity. It may vary slightly with the species.

The larvae are active, worm-like creatures. They live on organic matter found in the dust and on the dried blood in excreta of the adult fleas. The length of the larval stage varies from about a week to several months, depending on the food supply, temperature and humidity. The larva moults twice and then spins a silken cocoon within which it pupates. The pupal stage lasts for about eight to fourteen days in warm weather, but may be prolonged for months in cold weather.

Under ideal conditions the adult flea may live for months, and in some instances for as long as a year. When separated from its host the flea ordinarily lives only for a short time, but may, under suitable conditions, survive for weeks or months.

Control measures. While flea control on a large scale, or when undertaken to prevent the transmission of disease, is based on the control of the animal hosts, it may be necessary to institute measures for the eradication of fleas from buildings or rooms. At times basements or cellars, or even the rooms of barracks, may become infested with fleas from dogs, cats or rats.

The most important control measure is the elimination of the animal hosts, or in the case of pet animals, thorough cleansing of the animals in order to kill the adult insects. If the fleas are derived from rats, suitable rat control measures should be employed (page 814).

Pet animals may be freed of adult fleas by washing with a three per cent cresol solution, or a ten per cent emulsion of kerosene in soapy water. Dogs and cats may be disinfested with derris root powder. The powder should be dusted or rubbed lightly into the hair or fur, especially along the back of the animal, and allowed to remain for several days. The powder for this purpose should be prepared by mixing one part of the derris root powder with two parts of flour or corn-

starch. Pyrethrum powder may be used instead of derris root powder.

Fleas can be killed by fumigation with pyrethrum, hydrocyanic acid gas, or sulphur (page 828). They may also be destroyed by sprinkling the floor with crude naphthalene or powdered pyrethrum, at the rate of about one pound to every 50 to 100 square feet of floor space, and closing all doors and windows for from four to six hours. As soon as the room is opened, the floor should be thoroughly swept and the sweepings burned in order to kill the stunned fleas.

The eggs, larvae, pupae, and adults can be destroyed by removing all dust and debris and scrubbing all woodwork with soapy water containing from 10 to 15 per cent of kerosene. The suspension can be rendered more effective by the addition of about five per cent of cresol. Special care should be taken that all cracks, crevices and corners are thoroughly scrubbed. In basements or cellars having dirt floors, the floors should be well sprinkled or wet down with the emulsion.

Fleas can be eliminated from infested barns, barnyards or corrals, or their prevalence markedly reduced, by spraying with a creosote oil containing at least ten per cent of tar acids.

PHLEBOTOMUS
(*Sand Fly*)

Phlebotomus (moth midge, sand fly) is a small bloodsucking gnat-like fly or midge belonging to the order Insecta, family *Psychodidae* and genus *Phlebotomus.* There are many species of Phlebotomus and of these *P. papatasii* is known to be the insect vector of pappataci fever (*sand-fly fever*) (page 882), while several other species are thought to be capable of transmitting the disease. It has been demonstrated that *Phlebotomus argentipes,* and possibly other species of Phlebotomus, are capable of transmitting *Leishmania donovani,* the etiological agent of kala-azar (*Leishmaniasis*). Species of the genus Phlebotomus are widely distributed throughout the tropical and subtropical regions of the world. They are most prevalent when and where the atmosphere is hot and humid.

Habits and characteristics. Phlebotomus develops by complete metamorphosis. The eggs are deposited in dark, moist places, preferably in cracks and crevices of old stone

or brick walls or embankments, in rubbish and damp basements, or in the ground and debris around buildings. The eggs are oval, yellowish brown, and from 0.1 to 0.15 mm. in length. As a rule, about 40 eggs are laid separately over a period of several days. Usually the insect dies during or after oviposition. In hot humid weather the eggs hatch in from six to nine days. Cold or dryness may prolong the egg stage to as long as 20 days, or prevent development. Too much moisture will also inhibit or prevent hatching of the eggs. The presence of light will usually prevent the deposition of the eggs.

The larvae are worm-like creatures from two to four mm. in length. They are characterized by two long dorsal bristles on the terminal segment. The larvae are active and feed on organic material present in the breeding places. Given warm, moist weather, the larval stage lasts about four weeks, but may be greatly prolonged under unfavorable conditions. The larvae may remain dormant or hibernate for several months in dry, cold weather. Excessive moisture inhibits or prevents the development of the larvae.

The pupae are yellowish in color and the surface presents a number of small spines. They frequently lie free on the surface of the debris in the breeding place. The pupal stage lasts for from eleven to sixteen days.

The adult Phlebotomus is a minute insect, being only about one-twelfth of an inch in length. The female is a persistent and vicious bloodsucker and feeds on both warm and cold blooded animals. It is probable that blood is necessary for maturation of the eggs.

Phlebotomus are crepuscular and nocturnal in their biting habits and bite most freely when the air is warm, humid and still. They attack man most persistently on the hands, wrists, ankles or neck, but will bite any exposed portion of the body. During the day they hide and rest in dark, out of the way places inside and outside of buildings. They shun direct sunlight, but not artificial light unless it is very intense.

The flight range of Phlebotomus is limited and they do not disperse for any considerable distance from their breeding places. They are weak flyers and can make little or no progress against a breeze.

The bites of Phlebotomus produce quite severe irritation in many persons. Where these insects are numerous, the irritation and discomfort caused by the bites is frequently sufficient to exert a decidedly unfavorable influence on the morale and physical well being of troops.

Control measures. The control of *P. papatasii* is based chiefly on the elimination of breeding and hiding places. An area for a distance of from 100 to 300 yards around inhabited barracks or buildings should be cleared of all rubbish or vegetation which would afford breeding places. Cracks and holes in the ground should be filled and rough spots smoothed. Cracks and crevices in the walls of buildings, or other structures, should be filled or otherwise repaired. All debris and rubbish should be removed from basements and cellars. As far as practicable, sunlight should be admitted to all darkened places. Crevices or areas in which breeding cannot be controlled by other means should be thoroughly wetted with water daily.

Owing to its small size, unfed Phlebotomus can easily pass through ordinary metal screening or mosquito bars. Mosquito netting which will exclude Phlebotomus must have about 45 strands to the inch. Muslin may be used in lieu of netting. Three fold mosquito netting will exclude most of the insects. However, either the 45 to the inch mesh netting, muslin, or three fold mosquito netting interferes seriously with ventilation, and, as protection against Phlebotomus is required mostly on hot, humid nights when there is practically no air movement, great difficulty is usually experienced in obtaining adequate protection by these means.

Rooms may be ventilated and Phlebotomus excluded by so placing electric fans that currents of air are directed from the interior of the room through the open windows. The insects cannot enter the room against the breeze produced by the fans.

Repellents may afford a measure of protection. Those ordinarily employed consist of camphor or some one of the essential oils, such as oil of anise or eucalyptus, incorporated in a lanolin or vaseline base. They are rubbed over the exposed portions of the body.

The insects hiding within a building may be killed by fumigation. Sulphur or pyrethrum can be used for this purpose (page 809).

BEDBUGS

Bedbugs are cosmopolitan in their distribution and frequently become a serious pest in barracks and guardhouses. It has not been definitely proven that bedbugs transmit any disease to man, although they have been suspected of mechanically transmitting relapsing fever, leishmaniasis and, possibly, tularemia. As they are bloodsucking insects, it is possible that they may transmit any disease in which there is a blood stream infection. *Panstrongylus megistus* (*Triatoma megistus*), an insect which is closely related to the bedbug, is the usual transmitter of *Trypanosoma cruzi*, the etiological agent of South American trypanosomiasis.

Bedbugs belong to the order Hemiptera, family Cimicidae and genus Cimex. The two common species are *Cimex lectularius*, the bedbug of temperate and cold climates, and *C. hemipterus* (*C. rotundatus*), the bedbug of the tropics.

Bedbugs normally subsist solely on human blood. However, under abnormal conditions they will feed on the blood of accessible animals, such as rats and mice, or on birds. Bedbugs exist principally in houses, ships, railway trains or wherever they can live in close association with man.

Habits and characteristics. Bedbugs develop by incomplete metamorphosis. The eggs are operculated, white, oval in shape, and about one mm. long and 0.5 mm. in diameter. They are deposited in cracks and crevices in the furniture or in the walls, floor or ceiling of the room, under wall paper, or in other places which afford protection and concealment. The eggs are laid separately but tend to adhere to each other and form clumps.

In warm weather the eggs hatch in from four to ten days, but development may be much prolonged or entirely prevented by cold.

The larvae are yellowish white in color and resemble the adult, except in size and color. The reproductive organs and elytra (rudimentary wings) are missing in the larval form and do not appear until the third nymphal moult.

Given a food supply and warm temperature, the larva moults in four or five days and enters the first nymphal stage. It develops by moulting through three nymphal stages, each of which lasts from a week to ten days. At the end of the

FIG. No. 314. Common bedbug of the temperate zone, *Cimex lectularius*. (Photograph). (Courtesy of Lieut. Colonel James P. Crawford, Medical Corps, United States Army, Chief, Division of Entomology, Army Medical School, Washington, D. C.)

third nymphal stage, moulting again occurs and the insect becomes an adult.

Blood is required for the development of the larval and each of the nymphal stages. In the presence of an ample food supply, the time required for the development of the larval and nymphal stages varies from about four to six weeks in warm weather to as long as eleven weeks in cold weather. In the absence of food, the length of any of the immature stages may be indefinitely prolonged.

Bedbugs are nocturnal insects and, under ordinary conditions, they seek food only at night and hide in cracks and crevices during the daylight hours. When driven by hunger, they will, however, feed during the day or in the presence of strong artificial light.

Adult bedbugs are capable of surviving for long periods, in some instances for six months or more, without food. They may remain in vacated buildings for months and reappear when the buildings are reoccupied. They will also migrate from one building to another in search of food.

The bedbug is very sensitive to high temperatures and all forms, including the eggs, are killed in a few minutes by ex-

posure to a temperature of 113°F. in a humid atmosphere. The optimum temperature for bedbugs ranges from 60°F. to 98°F. and they are most active at temperatures of from 70°F. to 75°F. They become inactive at about 60°F., and are killed by prolonged exposure to a temperature below freezing.

Dissemination. Bedbugs are usually spread from place to place, or from building to building, in clothing, bedding, baggage or furniture. Barracks may become infested by insects being carried into them in the clothing or possessions of recruits or men returning from furlough. Bedbugs are frequently introduced into guard houses in this manner by prisoners returned from civil communities.

Control measures. Measures which promote general cleanliness of buildings will not prevent infestation with bedbugs, nor eradicate them after infestation has occurred. A scrupulously clean barracks may become infested with bedbugs and remain infested unless specific control measures are employed.

Fumigation is the most effective bedbug control measure, provided a gas is used which will penetrate into the depths of the cracks and crevices in the walls, floor and furniture. *Hydrocyanic acid gas* is a penetrating gas and, when properly used as a fumigant, it will reach and destroy all forms of the bedbug, including the eggs. *Sulphur dioxide,* when applied in the presence of ample moisture, will destroy the bedbug and its eggs, but owing to its low penetrating power it will not reach those which are hidden in deep cracks, behind wall paper, or are otherwise protected. Both hydrocyanic acid gas and sulphur dioxide are applied in the control of bedbugs in the same manner as described for the eradication of rats (page 828).

Liquid insecticides of various kinds are used to destroy bedbugs. An effective mixture for this purpose is kerosene containing ten per cent of cresol, or five per cent of cresol and five per cent of turpentine. If the latter is used, the cresol should be dissolved in the turpentine and the resulting mixture added to the kerosene. Kerosene alone may be used and is fairly effective. Extract of pyrethrum is also an efficient insecticide (page 807).

The efficacy of any liquid insecticide used to destroy bedbugs depends largely on the thoroughness with which it is applied. It must be so applied that it is forced into all cracks, crevices or

other places in which the bugs seek protection or lay their eggs. A fine, flexible paint brush and liberal quantities of the liquid should be used for this purpose. Care should be taken that all places in which bedbugs could hide are treated. Spraying does not, as a rule, produce satisfactory results.

Steam can be, and should be where practicable, used to eradicate bedbugs from mattresses, blankets and other bedding. The same methods are used as for delousing (page 960). Where steam disinfestors are not available, all bedding should be carefully searched for bedbugs and, if necessary, treated with gasoline, dry cleaned, or washed with hot water.

The joints, cracks, or other openings in iron beds or cots or other iron work and the cracks and crevices in concrete floors can be disinfested with good results by flaming with a blow torch.

Heat can be used in rooms or buildings to destroy bedbugs and their eggs. Direct exposure to a temperature of 113°F. will kill all forms, but it is necessary, in order to insure penetration of the heat into all cracks and spaces in the walls, floor, ceiling or furniture, that the air of the room be heated to a temperature of not less than 130°F. for at least 30 minutes. In squad rooms, the bedding, mattresses and clothing should be hung or arranged in such a way as to facilitate the penetration of the heat. This method has the disadvantage that, ordinarily, it is difficult to heat the air in a room to 130°F. with the facilities available. Also, unless the temperature of the outside air is relatively high, the expansion of the air within an air tight room is likely to break the windows.

It is extremely difficult to eradicate all bedbugs and eggs from a room or building with one treatment by any control measure, except fumigation with hydrocyanic acid gas. Usually, a few eggs will escape destruction and subsequently hatch. Consequently, when any measure, except fumigation with hydrocyanic acid gas, is employed, it should be repeated several times at intervals of from one week to one month, so as to destroy the immature forms before development is complete and oviposition occurs.

ROACHES

Roaches belong to the order Orthoptera and family Blattidae. There are many genera and species of roaches and their distribution is world wide. The common domesticated or house species found in America are *Periplaneta americana*, the American cockroach; *Blattella germanica*, the German cockroach or croton bug; *Blatta orientalis*. the European cockroach or black beetle, and *Periplaneta australasiae*, the Australian cockroach. While all these species are found in the United States, they vary greatly in prevalence in different parts of the country. Two species are seldom found together.

Habits and characteristics. Roaches develop by incomplete metamorphosis. The eggs are enclosed in a hard capsule which may be retained within the abdomen of the female insect until the larvae are ready to emerge or it may be deposited in a crack or crevice. The egg stage may last for weeks. The larvae are similar to the adults, except that they are much smaller. The larval stage may last for from six months to a year or longer.

The domestic roach will feed on practically any article of human food and will also gnaw woolen goods and leather. They frequently damage books in order to reach the paste used in the binding. They are nocturnal in their habits and tend to remain in concealment during the day and feed at night. In the temperate zone, they are found most frequently in kitchens and pantries where a food supply is readily available and where there is a certain degree of warmth.

The domestic roaches seek concealment in cracks in the walls and floors into which, because of their thin flat bodies, they can readily enter. They also hide behind any object which will shield them from light. Roaches may be introduced into a building in food supplies or they may migrate from building to building.

Roaches do not transmit any disease to man: They might, because of their habits, mechanically contaminate food with pathogenic organisms. They are, however, a decided pest, not only because of the damage they cause, but also because of the disagreeable odor they may impart to food.

Control measures. Practically every army kitchen which has been in operation for any length of time becomes infested

FIG. No. 315. Common roach, *Periplaneta americana*. (Photograph). (Courtesy of Lieut. Colonel James P. Crawford, Medical Corps, United States Army, Chief, Division of Entomology, Army Medical School, Washington, D. C.)

to a greater or less extent with roaches. The complete eradication of roaches from a kitchen is a difficult matter but can be accomplished by persistent effort.

The first step in the control of roaches is cleanliness. Food should be stored so that it is inaccessible to roaches. Scraps and particles of food should be properly disposed of and table tops and utensils should be kept free from grease. Special care should be taken that the kitchen is thoroughly cleaned at night and no food is left where it will be accessible to roaches during the night.

The most practical method of destroying roaches is to place powdered sodium fluoride in all cracks, crevices or other places in which roaches might hide. The powder should be applied with a small blower and the application should be repeated every few days until no more roaches are to be found. Shelves and table tops may also be dusted, but care should be taken not to contaminate food with the powder.

Pyrethrum is also an effective roach poison. The powdered pyrethrum is mixed with sodium borate, or with flour and sodium borate, in varying proportions. One such powder consists of five parts of flour, three parts of sodium borate and one part of powdered pyrethrum flowers. A stronger mixture is made by mixing one part of the pyrethrum powder with one part of sodium borate. If a powder containing flour is left in place for several days it tends to harden and is then less effective as a roach poison.

Powdered borax may be used as a roach poison but it acts more slowly than sodium fluoride. Pure borax or a mixture consisting of three parts of borax and one part of powdered chocolate, or flour, may be used.

The pyrethrum powders or powdered borax are applied in the same manner as sodium fluoride (*supra*).

Roaches tend to avoid poisoned food but poisoned pastes containing phosphorus or arsenic are sometimes used. One very effective phosphorus paste consists of one part of phosphorus, three parts of powdered talc and four parts of molasses. A poisoned paste may be employed effectively in drains, in spaces between and under floors or in walls, and, at times, in offices or libraries where it would not be desirable to use powder. Poisoned paste should not be used in kitchens or messes, or in places where

there is any danger that it will be eaten by children. Care must be taken to place phosphorus pastes where there will be no danger of fire should the phosphorus ignite.

Sprays consisting of kerosene or alcoholic extracts of pyrethrum are useful in reducing the number of roaches. These sprays are made as described on page 807. The spray should be applied to the cracks in the walls and floors, especially around the base boards.

Fumigation with hydrocyanic acid gas will kill all the roaches in a building, but this method would not ordinarily be justified or necessary. Other fumigants, such as sulphur, formaldehyde or pyrethrum. will destroy some of the roaches, but will not accomplish complete eradication because they do not penetrate into the deep hiding places of the insects.

Roach traps may be used where the insects are especially numerous, but generally some one of the other control measures will be found to be more effective. The German roach (croton bug) cannot be trapped in any considerable numbers. A simple roach trap consists of a deep vessel, jar or crock containing bait which will attract the insects by its odor. The fermented cornmeal fly trap bait described on page 801 is an effective roach bait. Sticks are placed against the outside of the vessel at such an angle that the roaches can climb to the upper edge, from where they climb or fall down to the bait within. They are unable to climb out of the vessel.

CONTROL OF ANTS

Many species of ants will, when attracted by a food supply, become pests in and around kitchens and messes. Primarily, measures should be taken to deny them food by rendering food supplies inaccessible. All food and debris should be promptly removed and food supplies should be stored in ant proof metal boxes. Where ants are numerous, they may be prevented from climbing onto tables by placing the legs of the table in cans or small pans containing kerosene or water, or oil soaked cloths may be placed around the table legs.

If an ant colony can be located, it may be destroyed by kerosene, gasoline or carbon disulphide. Poisons may be used and usually consist of borax or arsenic. A poison syrup can be made by dissolving sugar and borax in boiling water. The solu-

tion is taken up with small pieces of sponges which are distributed where they can be easily reached by the ants. A more effective but also more dangerous poison is made by dissolving one pound of sugar and 125 grains of sodium arsenate in a quart of water. This mixture is boiled and strained. When cool, it is distributed by means of small pieces of sponge. A small amount of honey will render poison syrups more attractive to ants. Great care must be exercised in the use of arsenic in kitchens and messes to prevent accidental poisoning of human beings. The poisoned syrup is collected by the ants and carried to their nests, where it kills not only the ants which collect it but also others in the nests.

Colonies of lawn or garden ants can be most effectively eradicated by the use of carbon disulphide. Carbon disulphide is a heavy, yellowish liquid which vaporizes at ordinary temperatures. The vapor when mixed with air is explosive. Several ounces of carbon disulphide are injected into the nest and the opening closed. The vapor will then penetrate into the recesses of the nest. Several additional holes for the injection of the carbon disulphide may be made by plunging a sharp stick down into the nest. If the colony is large, the nest should be covered with a wet blanket, or similar cloth, after the application of the carbon disulphide. More effective penetration can be obtained by removing the blanket after about five minutes and exploding the carbon disulphide vapor by means of a lighted paper or cloth tied on the end of a long stick. The force of the explosion will drive the vapor into all parts of the nest.

Small colonies can be destroyed by pouring kerosene or boiling water into the nest. Lawns or grass plots may be sprayed with a kerosene emulsion.

CHAPTER XXIV.

CONTROL OF VENEREAL DISEASE

The venereal diseases are those diseases which are ordinarily transmitted by sexual intercourse, and include syphilis, gonorrhea, chancroid and lymphogranuloma inguinale. Vincent's balanitis is sometimes regarded as a venereal disease (page 106). Although each venereal disease is a disease entity, the venereal diseases are considered as a group in so far as the general aspects of epidemiology and control are concerned.

SYPHILIS

Definition. Syphilis is a chronic, specific infectious disease due to *Treponema pallidum.* Typical acquired syphilis is manifested clinically by an initial lesion, or chancre, a secondary stage which is characterized by general constitutional involvement and accompanied by an eruption on the skin and mucous membrane, and a late or tertiary stage which is characterized by the occurrence of specific granulomata, visceral changes, and involvement of the central nervous system. Syphilis is protean in character and atypical manifestations are common.

The clinical manifestations of congenital syphilis are similar to those of acquired syphilis, except that no primary lesion occurs and there is a marked tendency towards an indefinite course of development.

Etiology. Syphilis is essentially an endemic disease. The causal agent, *Treponema pallidum,* is found in nature only in man. It is present in the chancre, in the secondary lesions, particularly in the mucous patches, in the blood and lymph during the more acute phases of the disease, in the lymph glands, and also in the spinal fluid and internal organs.

Treponema pallidum is readily killed by exposure outside the body. It can survive for only a short time in body fluids deposited on dishes, drinking glasses, towels or similar articles. It is easily destroyed by drying and by weak disinfectants, including soap.

Incubation period. The incubation period of syphilis from the time of infection to the appearance of the initial lesion is usually about three weeks, but may vary from ten to forty days, and, in rare instances, it may be as long as sixty days. The secondary period of incubation, that is, the period from the occurrence of the initial lesion to the appearance of the typical rash of the secondary stage, is usually about six weeks, but may be prolonged to as long as six months.

Susceptibility and immunity. There is no natural immunity to syphilis and all ages and both sexes are universally susceptible to the infection. A person having syphilis is resistant to reinfection, although superinfection without the production of a local lesion may occasionally occur. It is probable that an immunity to infection may persist for an indefinite period of time after the disease is cured.

Transmission. Except in very rare instances, acquired syphilis, as it occurs among troops, is contracted through sexual intercourse. The infectious organisms are inoculated through abrasions of the skin or membranes, but such abrasions may be only microscopical in size. The infection may be transmitted during the act of kissing. Occasionally, the infection is acquired by medical officers or enlisted men of the Medical Department through contact with the body fluids of infected persons during surgical operations or while dressing wounds or injuries. The general features of transmission are considered on page 1008.

Control measures. The control of venereal diseases, as described on pages 1008 to 1020, includes the general measures for the control of syphilis. Control measures which apply specifically to syphilis are chiefly those concerned with the diagnosis and treatment. Early diagnosis and prompt treatment of the individual case of syphilis are important factors in controlling the spread of the disease. Dark field examinations should be made of any suspicious sore. No ulcer should be diagnosed as nonsyphilitic until repeated dark field examinations of the exudate and negative Wassermann or Kahn tests

have shown that syphilitic infection is not present. All suspicious cases should be regarded as syphilis until proven otherwise.

The fact that prolonged treatment is required to effect a cure of syphilis renders the continuous supervision of treatment an important factor in the ultimate control of the disease. In order to insure control of the individual case, army regulations require that a syphilitic register (Form 78 Medical Department) be initiated and maintained for each person in active military service who has syphilis. The register contains the clinical history of the case and data relative to all treatment given. If the soldier is transferred to another station, the register is sent to the surgeon of his new station. When the patient is cured or leaves the service, the register is closed and sent to the Surgeon General. For *administrative purposes* a patient may be regarded as being "cured" when he has manifested no symptoms of syphilis for a period of one year during which he has received no treatment and no positive and at least two negative Wassermann and Kahn reactions have been obtained with the blood serum. The standard of cure should also require that the spinal fluid be normal on examination at the end of the one year period. From a clinical viewpoint the standard of cure should be based on a two year rather than a one year period.

GONORRHEA

Definition. Gonorrhea is an acute infectious disease caused by the gonococcus (*Micrococcus gonorrheae*) (*Neisseria gonorrheae*). Typical gonorrhea in the adult male is characterized clinically by an acute urethritis, a purulent urethral discharge and painful urination. Chronic gonorrhea is relatively common. It may be manifested by chronic inflammation of the urethra, prostatitis, seminal vesiculitis, epididymitis, arthritis and at times endocarditis, pyelitis or pyelonephritis. Infection of the eye produces gonorrheal ophthalmia.

Gonorrhea in the female is characterized by an inflammatory involvement of the urethra, vagina, Bartholin's glands and Skeene's glands, cervix, uterine canal and Fallopian tubes. Vulvovaginitis of gonorrheal origin is relatively common in small children, especially among those living in institutions.

Etiology. The gonococcus is found naturally only in man. It is present in large numbers in the inflammatory ex-

udates and discharges, particularly during the acute stages of infection. It is a delicate organism and is easily destroyed by drying and by weak disinfectants.

Gonorrhea is essentially an endemic disease. Epidemics of vulvovaginitis occur among the children in institutions, but gonorrhea does not occur in true epidemic form among adults.

Transmission. Gonorrhea is practically always transmitted among adults by sexual intercourse. *Very rarely* gonorrheal ophthalmia may be caused by gonococci transmitted by indirect contact through the medium of inanimate objects.

The infection is communicable as long as the organisms are present in any of the discharges. While true carriers of gonorrhea do not exist, the chronic case is, in effect, a carrier of the infection and every patient should be regarded as capable of transmitting the infection until cured. One accepted standard of cure is as follows:

a. Disappearance of all evidence of urethral discharge.

b. Disappearance of all shreds from the urine.

c. The material expressed from the urethra by prostatic massage must be negative for gonococci on four successive examinations at weekly intervals.

d. The discharge resulting from the inflammatory reaction following the dilation of the urethra with sounds must be negative for gonococci.

Where laboratory facilities are available, no case of gonorrhea should be regarded as cured until negative cultures have been obtained from the material expressed by prostatic massage and from urethral swabs.

Control measures. The general measures for the control of venereal diseases as described on page 1008 include the control of gonorrhea.

CHANCROID
(*Soft chancre*)

Definition. Chancroid is a specific infectious disease manifested by characteristic ulceration, usually on the genitals. Single or multiple ulcers may be present and the infection is auto-inoculable. Usually, there is a suppurative adenitis involving the inguinal lymph glands. As a rule, there are no systemic symptoms.

Etiology. Chancroid is caused by the bacillus of Ducrey. The infection occurs most frequently in the presence of uncleanliness and faulty personal hygiene. The causal organism is easily destroyed by weak disinfectants.

Incubation period. The incubation period of chancroid is usually from two to three days, but may be as short as twenty-four hours or somewhat longer than three days.

Susceptibility and immunity. Susceptibility is universal and one attack affords no immunity to future infections.

Transmission. Chancroid is, in the vast majority of instances, transmitted by sexual intercourse. Extragenital infection may be caused by inoculation of the pus from ulcers or glands. The organisms are inoculated through cuts or abrasions of the skin or mucous membranes.

Control measures. The measures employed for the control of venereal diseases generally, as described below, include the control of chancroid. Specifically, cleanliness and the use of soap and water are effective control measures.

Any ulcer on the genitals should be regarded as a chancre until proven otherwise. The diagnosis of chancroid should not be made until thorough and repeated dark field examinations of the exudates fail to reveal the presence of *Treponema pallidum*. Wassermann or Kahn tests should be made on the blood of all cases diagnosed as chancroid prior to release from observation.

LYMPHOGRANULOMA INGUINALE

(Venereal lymphogranuloma, Lymphogranulomatosis inguinale, Lymphogranuloma venereum, Climatic bubo, Nicholas-Favre disease)

Definition. Lymphogranuloma inguinale is a subacute infectious disease characterized in the male by a primary lesion consisting of a herpetiform ulcer on the external genitalia followed by unilateral or bilateral involvement of the inguinal lymph glands, fever, anorexia and prostration. In the female the disease is manifested by genito-ano-rectal involvement and esthiomeme.

The *Frei intracutaneous test* is the most reliable diagnostic and differential diagnostic procedure. The *Frei test* is performed by injecting the specific antigen intracutaneously in the

forearm. A control injection of a like amount of saline solution may be used but is not ordinarily necessary.

Within 24 to 48 hours a *positive Frei reaction* presents an area or zone of erythema from one to several inches in diameter with, in most instances, a papule 10 millimeters or more in diameter. The papule may be surrounded or surmounted by vesicles or pustules which may develop to form an ulcerated area. A *negative Frei reaction* may also show an area of erythema and papule formation, but the zone of erythema is relatively small and the papule is seldom more than 7 millimeters and is usually about 4 or 5 millimeters in diameter.

Frei antigen ordinarily consists of heated and properly diluted material from an infected gland suspended in saline solution. Recently, mouse brain antigen has been prepared which produces good results.

Etiology. It is quite probable that lymphogranuloma inguinale is caused by a filterable virus, although this has not, as yet, been definitely proven.

Lymphogranuloma inguinale should be differentiated from granuloma inguinale (*granuloma venereum*) which is a separate disease entity and is not caused by a filterable virus (page 1050).

Incubation period. The incubation period of lymphogranuloma inguinale from the time of exposure to the appearance of the primary lesion is usually about twelve days, but varies from a few days to three weeks or more. The incubation period from exposure to the first demonstrable enlargement of the lymph glands varies from ten days to two months but is from two to three weeks in most cases.

Susceptibility and immunity. Apparently susceptibility to lymphogranuloma inguinale is universal. An attack of the disease does not confer immunity to the infection.

Transmission. Lymphogranuloma inguinale is transmitted by direct contact and in practically all instances by sexual intercourse. The secretions or discharges from the lesions are infective.

Granuloma inguinale, with which lymphogranuloma inguinale may be confused, may be transmitted by sexual intercourse, but it is generally believed that the infection is frequently transmitted in other ways.

Prevalence and importance. Lymphogranuloma inguinale is prevalent in the tropics and among the prostitutes in tropical cities. The disease is relatively rare in the United States.

In the past there has been much confusion in diagnosis, and statistics relative to the prevalence of the disease among American troops are not available. It is probable that many of the cases of so-called non-venereal bubo were actually cases of lymphogranuloma inguinale.

In June, 1937, instructions were issued by the War Department that lymphogranuloma inguinale occurring among troops would be reported as a venereal disease. From June through September, 1937, 10 cases were reported from the Canal Zone, and 17 from military organizations in the United States.

Control measures. Measures for the control of other venereal diseases (*infra*) apply also to the control of lymphogranuloma inguinale.

GENERAL PREVALENCE AND IMPORTANCE

The relative incidence of venereal disease in military organizations is very largely dependent upon the extent to which control measures are enforced and the opportunities for exposure to infection. The prevalence of venereal disease in the United States Army as a whole has exhibited a downward trend since the World War as shown in the following table. Without doubt, the continuous application of suitable control measures within the army has been a determining factor in effecting this decrease, although it is probable that some influence has been exerted by procedures adopted by civilian communities to control prostitution and venereal disease.

Prevalence of Venereal Diseases in the United States Army during the Years 1920 - 1935, inclusive.

Rates per 1000 strength per annum.

Year	Syphilis	Gonorrhea	Chancroid	All Venereal Diseases
1920	13.92	48.84	16.23	78.98
1921	12.35	42.31	12.11	66.76
1922	13.12	39.56	11.95	64.63
1923	13.67	33.59	11.91	59.16
1924	13.73	33.16	9.15	56.05
1925	11.70	31.08	9.46	52.25
1926	11.91	29.60	8.45	49.96
1927	10.72	30.02	8.98	49.73
1928	11.16	29.03	7.98	48.18
1929	11.55	28.77	8.01	48.33
1930	11.90	28.30	7.50	47.70
1931	11.50	26.30	7.80	45.60
1932	11.90	25.40	4.70	42.00
1933	9.90	21.00	3.50	34.40
1934	9.10	20.60	4.70	34.40
1935	7.80	22.30	5.10	35.10

Under average conditions, venereal disease is by far the most important cause of noneffectiveness among troops. During the World War, venereal disease ranked second only to influenza as a cause of disability and absence from duty. The following table shows for comparative purposes the days lost from duty per 1000 strength per annum during the World War period for the five leading diseases.

Days lost from duty for the five leading diseases during the World War.

Rates per 1000 strength per annum.

Disease	Rate per 1000
Influenza	7.09
Venereal diseases (all)	4.52
Mumps	2.58
Tuberculosis (all)	2.51
Bronchitis	2.18

During peace, the time lost from duty because of venereal disease constitutes about 18 per cent of the time lost because of all diseases and is far in excess of time lost due to any other one disease.

The prevalence of venereal disease in the civilian population of the United States has not been accurately determined. Studies have shown that from sixty to seventy-five per cent of all prostitutes present demonstrable evidence of venereal disease, but it is probable that the actual incidence is considerably higher. The chances that a prostitute will escape all venereal infection are remote, although she may not be capable of transmitting the infection at all times.

GENERAL CONTROL MEASURES

The source of venereal disease is, in the great majority of instances, the infected prostitute. Venereal diseases do not spread from soldier to soldier, except in very rare instances when syphilis may be transmitted by direct contact other than sexual. The spread of venereal disease among troops is influenced by a number of factors that do not obtain in other diseases. The source of infection, that is, the infected prostitute, is beyond military jurisdiction and is not, therefore, subject to direct control by military agencies. Venereal infection is acquired as a result of gratifying the fundamental instinct of reproduction, and exposure to infection, and the consequent acquisition of a venereal infection is, therefore, a purely voluntary act on the part of the individual.

Fundamentally, measures for the control of venereal disease are designed either to prevent exposure to venereal infection or to prevent the development of the infection in the exposed individual. The measures employed to control exposure consist of the control of prostitution, educational and recreational measures, and deterrent laws and regulations. The development of infection in the exposed individual is controlled by prophylaxis, the effectiveness of which is dependent on the training and discipline of the troops, the enforcement of regulations designed to compel reporting for prophylactic treatment, and the efficiency with which the prophylactic treatment is given.

Aside from the actual application of the prophylaxis, the measures for the control of venereal disease are chiefly adminis-

trative rather than technical in character. Consequently, the discipline, training and administration of organizations are the principal basic factors in the control of venereal disease and are relatively more important in this field than in the control of any other disease.

Control of prostitution. The prostitute is practically the sole source of venereal infection among troops, and control of the source of infection can, therefore, be effected only by the control of prostitution. As the control of prostitution in communities adjacent to military posts and camps is beyond military jurisdiction, it can be accomplished only by civilian authorities, except possibly where civilian communities are placed under martial law. Military authorities can influence and promote the control of prostitution through cooperation with civilian authorities in ways which vary with and depend upon the local economic and political situation. Frequently, by working with civic organizations and clubs, public opinion can be influenced to secure the adoption, or the enforcement, of laws which will restrict the activities of the prostitute. In other instances, data relative to the individuals from whom soldiers acquire venereal infection will aid civilian health authorites to locate the infected prostitute and detain her for treatment. If necessary, means can usually be found by which political or economic pressure can be brought to bear on the responsible civilian agencies which will force action to control prostitution in the vicinity of military stations.

There are two generally recognized methods of controlling prostitution—regulation and suppression. Regulation of prostitution, in its simplest form, consists of an attempt to restrict or segregate all recognized professional prostitutes within a certain area. Regulation may also include the registration of all prostitutes, the medical inspection of prostitutes for venereal disease, and various rules relative to the operation of houses of prostitution. Regulation is no longer countenanced anywhere in the United States as a legitimate means of controlling prostitution. Occasionally, a municipality will allow houses of prostitution to operate for a time, but public opinion will not permit their legal recognition.

Regulation of prostitution serves to promote rather than to limit the spread of venereal disease, in so far as troops are concerned. This method of control augments the accessibil-

ity of the prostitute and facilitates the practice of prostitution. The medical inspection of prostitutes, as practiced under conditions which surround regulated prostitution, is of practically no value in detecting or eliminating the infected prostitute.

Suppression of prostitution is the enactment and enforcement of laws forbidding the practice of prostitution under any guise. Under such laws, the open operation of houses of prostitution is prevented and the activities of the prostitute are restricted. Suppression does not eliminate the prostitute, as prostitutes are always present in any civilian community of any considerable size. It does, however, greatly reduce exposure to venereal disease by rendering the practice of prostitution more difficult and by making the prostitute less accessible.

While the suppression of prostitution is a police function, the laws which make prostitution illegal also facilitate the enforcement of measures for the direct control of venereal disease by health authorities. Such measures consist, generally, of the examination for venereal infection of women arrested for soliciting or for prostitution and their detention in institutions and hospitals for venereal disease treatment until they are no longer infectious. In some states, civilian physicians are required to report venereal disease cases in order to insure continuation of treatment until a cure is effected.

Educational measures. The primary purpose of educational measures is to reduce the number of venereal infections by providing the individual soldier with accurate information regarding the spread of venereal infection, the effects of venereal diseases on the human body, and the methods of prophylaxis. The individual soldier should be thoroughly informed regarding the necessity for chemical or mechanical prophylaxis in avoiding venereal disease, and the instruction given him by medical officers and company officers should stress the prevention of infection by means of prophylaxis.

The educational features of venereal disease control should be, for the larger part, conducted by medical officers and by the company commander of the troops concerned. The instructions given by medical officers should deal with the technical and scientific aspects of venereal disease, especially with transmission of the infection, the effect of venereal diseases on the body, and the means by which infection can be

avoided. Special emphasis should be given to the value and limitations of prophylaxis.

As a rule, the formal instruction given by medical officers is in the form of talks to relatively large groups of enlisted men and to officers below field grades. A talk on venereal disease should be most carefully prepared. The use of scientific terms should be reduced to a minimum, but on the other hand, slang terms should be scrupulously avoided. In delivering talks on veneral disease, medical officers should deal only with proven facts of a medical nature and should carefully avoid sensational statements or those consisting of half truths. Sentimental appeals have no place in a medical officer's lectures on venereal disease. A talk on venereal disease should never be read and notes should be used as little as possible. Properly prepared charts and lantern slides are valuable aids and should be employed whenever practicable. It should always be remembered that a carelessly prepared or a poorly presented talk on venereal disease may do more harm than good.

The company commander is in many ways one of the most important factors in the control of venereal disease and his attitude towards the control of venereal disease will, to a large extent, be reflected by the actions of his men. All company officers should, therefore, be well versed in the nature of venereal diseases and the means by which they can be controlled.

The activities of the company commander in the control of venereal disease in his company are largely of an administrative and disciplinary nature. He should instruct the members of his command relative to the effect of venereal disease on the efficiency of the individual and the unit. He is responsible that each man understands fully the penalties which may be incurred by failure to take the prophylaxis after exposure to venereal infection and that he is conversant with the laws pertaining to forfeiture of pay when incapacitated for duty by venereal disease. The company commander should personally interview each recruit and explain to him the laws and regulations concerning venereal disease and its prevention.

Formal lectures on the prevention of venereal disease may occasionally be given by persons, other than medical officers and company commanders, who are especially qualified in this particular field. Chaplains and welfare workers may

discuss the moral and social aspects of venereal disease. Here again, however, as in the case of instruction given by medical officers, sensational or illogical statements will do vastly more harm than good.

Recreation. Recreational facilities, such as well equipped day rooms, reading rooms, service clubs and gymnasiums, serve to induce a certain proportion of the troops to remain in the post during a larger part of their off-duty time, and to this extent decrease the opportunities for exposure to venereal disease. Athletic contests, motion picture shows, band concerts or any other activities which provide wholesome interests for troops and reduce the period during which the soldier must, by his own efforts, find recreation and entertainment are likewise important factors in reducing the number of exposures to venereal infection.

Value of education and recreation in control of venereal disease. Venereal disease control measures of an educational and recreational nature will, if properly employed, reduce the total number of exposures but will not, where prostitutes are accessible to the troops, prevent all exposure to infection. The psychological effect resulting from a knowledge of venereal disease, together with an interest in recreational and other hobbies or avocations will cause a number of the men to avoid any sexual intercourse with prostitutes. The same factors will, in other instances, reduce the number of exposures contracted by the individual man. There are, however, in every command a certain number of men whose relations with prostitutes are in no wise affected by any educational or recreational control measures. Consequently, while these measures do serve to decrease the total exposure rate, additional methods must be employed either to reduce still further the exposure to venereal infection or to prevent the development of disease following exposure to infection. Such measures consist of deterrent laws and regulations and prophylaxis.

Educational measures are also of great value in inducing men to report for prophylactic treatment within a short time after exposure. Properly conducted instruction is usually accompanied by a relatively high prophylactic rate or, in commands which have previously had a high venereal disease rate, by an increase in the prophylactic rate and by a decrease in the incidence of venereal disease.

Chemical prophylaxis. Chemical prophylaxis consists of the application of disinfectants for the purpose of destroying the infectious agents of venereal disease immediately after exposure and thus preventing invasion of the tissues, and the consequent development of the disease. The causal agents of all venereal diseases are readily destroyed by weak disinfectants. Ordinarily, soap, a solution of mercuric chloride, calomel ointment and a silver salt solution, usually protargol, are used as prophylactic agents. Other disinfectants, such as solutions of some one of the phenol compounds, potassium permanganate or alcohol may be successfully employed. The disinfectants which are employed in the military service at the present time consist of soap and water, 1-1000 solution of mercuric chloride, two per cent solution of protargol, and 30 to 33 per cent calomel ointment.

In order for the chemical prophylaxis to be most effective in preventing venereal disease, it must be properly applied. Experience has shown that while the prophylactic treatment can be self administered by the individual and will afford protection from venereal disease when properly applied by the individual, nevertheless, the best results are obtained when it is administered by trained personnel at a venereal prophylactic station. Consequently, venereal prophylactic stations are, as a rule, established wherever troops are assembled and all military personnel who expose themselves to venereal infection are required to report at a venereal prophylactic station for prophylactic treatment.

The venereal prophylactic station is operated by specially trained Medical Department enlisted men under the supervision of the surgeon. It consists essentially of the necessary equipment for the administration of the prophylactic treatment and for making and keeping the required records. An ample supply of warm water should be available. In small posts or camps where only one station is established, it is usually located in the dispensary or station hospital. At the large camps or posts, several stations should be established and so located that they will be easily accessible to troops returning to the camp or post. Where necessary, stations may be established in adjacent civilian communities.

The general efficiency of venereal prophylaxis as a control measure is dependent to a very considerable extent on the willing-

ness of troops to report for treatment after exposure. The degree of cooperation which can be obtained in this respect is, in part, determined by the manner in which the prophylactic station is conducted. The first requirement for the proper operation of a prophylactic station is well trained, intelligent and efficient attendants. The technique for administration of the prophylaxis and the rules governing the operation of the station should be kept posted in the station at all times. Frequent inspections should be made by the responsible medical officer.

A high degree of cleanliness and orderliness is essential to success in the operation of a prophylactic station. A prophylactic station should be similar in this respect to an operating room in a hospital.

The station should be so arranged that the prophylactic treatment can be given in private. All boisterousness, joking or loafing should be strictly prohibited. Otherwise, men who should receive the prophylaxis will risk infection rather than report at the station.

As a soldier who does not receive prophylactic treatment and contracts a venereal disease is subject to trial by court-martial, proper records must be kept of the prophylactic treatment given. The official record of each prophylactic treatment administered is made on Form 77, Medical Department. The data recorded include the name, rank and organization of the soldier, the date and hour of intercourse, the date and hour of treatment, the presence or absence of venereal disease, the name of the attendant administering the prophylaxis, the signature of the soldier receiving the treatment, together with such other information as may be required by local conditions or orders.

The records should be authenticated daily by the initials of the officer in charge of the station. A certificate signed by the attendant in charge of the prophylactic station should be furnished each individual receiving prophylactic treatment, showing his name, rank and organization, and the date, place and hour of treatment. This certificate should also bear the signature of the individual receiving the treatment. If the soldier receiving the treatment is a member of an organization other than the one operating the prophylactic station, a duplicate certificate should be forwarded to the surgeon of the command to which he belongs. The records made on Form 77, M. D., should be kept on file in the prophylactic station for at least three months, after which

they may be destroyed or otherwise disposed of in accordance with local orders or army regulations.

Method of applying venereal prophylaxis. The minor details of the technique of administering the venereal prophylaxis may vary somewhat but the same basic methods are employed throughout the army. The individual reporting for prophylactic treatment should first be thoroughly examined for venereal disease. He should urinate, if possible, immediately prior to the beginning of the treatment. The genitals and the contiguous surfaces of the thighs and abdomen are then thoroughly washed with soap and water. The soap is a disinfectant and also serves to remove substances which would interfere with the action of disinfectants which are to be subsequently applied. The same area is then bathed and the soap removed with a 1-1000 solution of mercuric chloride. From four to six c.c. of a two per cent solution of protargol are then injected into the urethra and retained for five minutes. Finally, calomel ointment is rubbed thoroughly over all surfaces of the genitals. A paper towel or napkin should be used to protect the clothing. All records should be completed at the time the prophylaxis is given.

The individual prophylactic treatment has not, as yet, been shown to be nearly as effective as a general control measure as the prophylaxis administered by trained attendants at a prophylactic station. It is, however, a valuable measure when properly used immediately after intercourse. In some instances, it may be found desirable to issue individual prophylactic treatments, to be used where a prophylactic station cannot be reached until considerable time has elapsed after intercourse, or where men are going on furlough or pass to places where no prophylactic stations are available.

The material for individual prophylactic treatment is usually prepared in the form of a packet and consists of calomel ointment containing from one to three per cent of phenol and a small quantity of silver salt solution, usually protargol. A soap or an ointment containing a disinfectant is useful and a variety of such compounds have been advocated for individual prophylaxis. They have the advantage that they do not stain the clothing and can be dispensed in collapsible tubes.

The effectiveness of any individual prophylactic treatment depends upon it being properly and promptly used after intercourse. Where individual prophylactic packets or tubes are is-

sued, or otherwise made available for the troops, every soldier should be carefully and thoroughly instructed in the method of using them.

Thorough washing of the genitals and the adjacent surfaces of the thighs and abdomen with soap and water is a most valuable prophylactic measure and all troops should be instructed that, whenever practicable, this precaution should be taken immediately after intercourse.

Value of chemical prophylaxis in venereal disease control. Chemical prophylaxis is the principal measure available for the control of venereal disease among troops. Desirable as it might be to prevent all sexual intercourse between troops and prostitutes, it must be recognized that there is no method by which this result can be accomplished under ordinary conditions. Educational measures, recreational and interest diverting activities, and restrictive and deterrent laws and regulations will decrease exposure to venereal disease but, nevertheless, a considerable number of the individual members of a command will from time to time have intercourse with prostitutes. These men can be protected by chemical prophylaxis so administered that it will prevent the development of a venereal disease.

As chemical prophylaxis is effective only when it is applied before the organisms invade the tissues, any delay which may intervene between sexual intercourse and the application of the prophylactic serves to decrease proportionally the chances that the prophylactic will prevent infection. A number of studies have been made by various workers for the purpose of determining the degree of protection afforded by prophylactic treatment but, owing to the lack of controls, results which are accurate from a strictly scientific viewpoint have not been reported. However, conservative estimates based on field experience and statistical observations indicate that the chemical prophylaxis prescribed by the War Department will prevent the development of venereal disease in more than 90 per cent of actual exposures to infection, if applied within one hour after intercourse. Estimates based on similar experience and observation also show that when applied five and six hours after intercourse the prophylactic treatment is effective in about 50 per cent of those who would in the absence of prophylaxis develop a venereal disease. Prophylactic treatment may afford protection in some cases when administered as long as from twelve to twenty-four hours after intercourse.

An increase in the prophylactic rate may be due to more exposures and be accompanied by a proportional increase in the prevalence of venereal disease. However, given a situation into which no factor has been introduced which would cause an increase in exposure, an increase in the prophylactic rate is almost invariably accompanied by a decrease in the veneral disease rate.

Mechanical prophylaxis.. The condom affords the only practicable mechanical protection against venereal infection. Where properly used, the condom is effective in preventing gonorrheal infection and, to a less extent, syphilis, chancroid, or lymphogranuloma inguinale. The gonococci are infective only in the urethra which is protected by the condom, while the infective agents of the other three venereal diseases may be inoculated into the skin or tissues of the genitals or adjacent body surfaces that are unprotected by the condom.

Troops should be encouraged to use the condom for protection against venereal infection, and condoms should be made available to them, either free of cost or by sale for a nominal sum. However, even though a condom is used, the exposed individual should be required to obtain the chemical prophylaxis at a prophylactic station.

Restrictive and deterrent measures. The restrictive and deterrent measures employed in the control of venereal diseases consist of penalties for failure to secure prophylactic treatment after exposure, forfeiture of pay while incapacitated for duty because of venereal disease and trial by court-martial for contracting a venereal disease through misconduct. These measures are intended to deter men from indulging in illicit sexual intercourse, and to induce them to report for prophylactic treatment as soon as possible after exposure.

Failure to secure prophylactic treatment. Under existing army regulations, any member of the army who indulges in illicit sexual intercourse and does not report for prophylactic treatment within a reasonable time thereafter may be tried by court-martial for disobedience of orders. Usually, an enlisted man is tried by a summary court, in which case the maximum penalty is confinement with hard labor for one month and forfeiture of two-thirds of his pay for a like period. An enlisted man may, however, be tried by a special court and a heavier penalty given. In practice, where a man is found to have venereal disease and there is no record showing that he received

prophylactic treatment within the maximum limits of the period of incubation, he is generally considered to have violated the orders relative to venereal prophylaxis.

This measure serves to compel the individual to report for prophylactic treatment and is, therefore, a valuable control measure. It does not, however, insure that the prophylactic treatment will be obtained within the proper time after intercourse, as there is no way by which the time of intercourse can be determined, except by statements made by the man receiving the prophylaxis. It has the disadvantage that of those who fail to take the prophylactic treatment, only those who develop a venereal disease are detected and penalized.

Forfeiture of pay during absence from duty because of venereal disease. The Act of May 17, 1926, provides that no person on active duty in the military service who shall be absent from his regular duties for more than one day at any one time on account of the direct effects of a venereal disease due to his own misconduct, shall be entitled to pay for the period of such absence: *Provided*, That such absence is within a period of one year following the appearance of the initial symptoms of such venereal disease and regardless of whether the appearance of the initial symptoms occurs prior or subsequent to the date of entry into the service. It is further provided by this Act that each person whose pay is forfeited for a period in excess of one month at any one time shall be paid for necessary personal expenses the sum of five dollars for each full month during which his pay is forfeited.

This law is not primarily intended to serve solely as a disease control measure, but is based on the fact that when a soldier contracts a venereal disease through illicit sexual intercourse, he has, by a voluntary act on his part, rendered himself incapable of performing duty. He is not, therefore, under the law, entitled to receive pay. Under these circumstances pay is forfeited not as punishment for the commission of a criminal act, but because of failure to fulfill an existing contract between the individual and the Government. Therefore, no trial by court-martial is required. As in the great majority of instances, a venereal infection is acquired through illicit sexual intercourse, any man found to have a venereal disease is usually considered for the purposes of this Act to have contracted the infection as the re-

sult of illicit sexual intercourse, unless it can be shown that the infection was innocently acquired.

Trial by court-martial for contracting a venereal disease. Assuming that venereal infection, when acquired through illicit sexual intercourse, is acquired as the result of misconduct on the part of the individual, any soldier who contracts venereal disease in this manner may be tried under the provision of the 96th Article of War for wilful misconduct which renders him unfit to perform his military duty. This measure is seldom invoked, except during war when a venereal disease might be wilfully contracted in order to avoid dangerous duty or as a means of evading military service.

Physical inspections for evidence of venereal disease. Occasionally, individuals may endeavor to conceal venereal disease in order to avoid the penalty for failure to take prophylactic treatment, loss of pay while absent from duty, or restriction during the infectious stage. Such concealment deprives him of treatment, or, if he receives treatment from a civilian physician, it subjects him to the harmful effects resulting from the performance of duty during the acute stages of the disease.

Under the provisions of army regulations, all enlisted men are routinely inspected in order to detect hidden cases of venereal disease. Army regulations require that troops be inspected once each month for physical defects of all kinds, including venereal disease. The date and hour of this inspection are, as a rule, prescribed in orders and are therefore known to all troops prior to the time of inspection. Consequently, the clinical signs by which the inspector can detect the presence of venereal infection may be successfully concealed, especially in the case of mild gonorrhea. In order to obviate this difficulty, special inspections for venereal disease should be conducted from time to time, usually about once a month. These inspections are the most effective when held immediately following some military activity, such as drill, while the troops are still in formation and without prior knowledge on the part of those who are to be inspected.

Physical inspections are conducted by medical officers, preferably in the presence of an officer of the company or other unit being inspected. As a rule, they are held in the barracks or tents of the unit. It is essential that the men in-

spected be checked by a roster of the organization and that the inspection include all enlisted members of the command, except married men of good character. Noncommissioned officers are inspected separately.

Properly conducted physical inspections are of great value in the control of venereal disease, in that they tend to prevent an infected individual from concealing a venereal disease and consequently failing to receive proper treatment. Missed cases of venereal diseases do not, however, as in the case of the other infectious diseases, serve as sources from which infection will spread directly to other members of the command.

Treatment as a control measure. The prompt and adequate treatment of persons having a venereal disease until they are no longer infectious is a most effective method of controlling the spread of venereal diseases in the civil population.

It is essential that soldiers having venereal disease do not serve as sources of infection in civilian communities, and, consequently, all those who contract a venereal disease should be restricted to the station or camp until the infectious stage of the disease is past.

CHAPTER XXV.

CONTROL OF MISCELLANEOUS DISEASES

YAWS
(*Framboesia tropica, Pian*)

Definition. Yaws is a specific infectious disease which is manifested clinically by the development of a primary lesion (*mother yaw*) or papule, followed by a secondary or generalized stage. The secondary stage is characterized by a cutaneous eruption consisting of papules which develop into fungating, granulomatous lesions. A third or tertiary stage may occur and is characterized by extensive ulceration of the skin and underlying tissues, and, in some instances, by involvement of the blood vessels and bones. The Wassermann and Kahn reactions are positive in the typical, untreated case of yaws.

Yaws is in many respects quite similar to syphilis, and some authorities believe that yaws and syphilis are different types of the same disease, or that yaws is epidemic syphilis, the characteristics of which are modified by racial and hygienic factors. However, there is, as yet, insufficient evidence to support the assumption that yaws and syphilis are the same disease entity.

Etiology. Yaws is caused by *Treponema pertenue.* Geographically, yaws is limited to tropical and sub-tropical regions, and it is probable that climatic factors are of etiological significance.

Incubation period. The incubation period from exposure to the appearance of the primary lesion is usually from three to four weeks. The secondary incubation period, from the appearance of the primary lesion until the onset of the secondary stage, is usually from six weeks to three months.

Susceptibility and immunity. The natives of tropical countries appear to be generally susceptible to yaws. The white race is apparently highly resistant to the disease. Where the disease is prevalent, it occurs most frequently among children, probably because of the greater opportunities for infection. It has not been definitely determined whether or not an attack of yaws confers immunity to reinfection or to superinfection.

Prevalence and importance. While yaws is a disease of the tropical and sub-tropical regions of the world, it varies greatly in prevalence in different localities and countries. It is common in the West Indies, in tropical America, in the Philippine Islands, and in the Pacific Islands, generally. It is also prevalent in the equatorial regions of Africa and in the Malay Peninsula and Siam.

From a military point of view, yaws is not an important disease. Cases may occur occasionally among native troops.

Transmission. Yaws is probably transmitted in the majority of instances by contact, with the transfer of the infected discharges from the lesions through an abrasion of the skin. Insects, particularly flies, may play an important role in the transmission of the disease. The primary lesion usually develops on an exposed portion of the body. It seldom occurs on the genitals and sexual intercourse is apparently not an important factor in the transmission of the disease.

Control measures. Every case of yaws occurring among troops should be isolated to prevent contact with others, and given adequate treatment. Where troops are stationed or operating in sections where yaws is prevalent among the native inhabitants, special attention should be given to the disinfection of minor wounds and abrasions of the skin, to preventing or minimizing contact between troops and natives, and to the cleanliness and personal hygiene of the individual soldier. Measures should be taken to control house flies and blood sucking arthropoda.

The control of yaws among native populations is largely a question of removing the sources of infection by rendering cases noninfectious by prompt and thorough treatment. The arsphenamines, especially salvarsan and neosalvarsan, are generally used in the treatment of yaws. The bismuth prep-

arations and sulpharsphenamine are also effective and, as these compounds are cheaper and more easily administered, they are usually preferable for use in the treatment of a large number of patients.

INFECTIOUS JAUNDICE

(*Spirochetal jaundice, Spirochaetosis icterohaemorrhagica, Weil's disease, Epidemic jaundice*)

Definition. Infectious jaundice (spirochetal jaundice) is an acute infectious disease characterized by an abrupt onset, jaundice, muscular pains, fever, prostration, albuminuria and enlargement of the spleen and liver. The jaundice usually appears on the second to the fourth day of the disease. Epistaxis is relatively common and intestinal or subconjunctival hemorrhages may occur. Relapses may occur and convalescence may be prolonged.

Etiology. Infectious jaundice is caused by *Leptospira icterohaemorrhagiae* (*Spirochaeta icterohaemorrhagiae*). The organism is present in the blood, urine, and possibly in the feces. It is present in the blood during the first few days of the disease and in the urine after about the tenth day. The organisms may be excreted in the urine for as long as from forty to sixty days after the onset of the disease.

Rats constitute an animal reservoir of infection and about ten per cent of all rats examined harbor *L. icterohaemorrhagiae*. The organisms are present in the kidneys of rats, and may also be found in other organs and in the blood. They are excreted in the urine and also in the feces.

L. icterohaemorrhagiae is quite readily destroyed by disinfectants, although it will live for several days in wet soil and probably for some time in water.

Epidemics of catarrhal jaundice occur which apparently are not associated with *L. icterohaemorrhagiae*. Clinically, this type of jaundice resembles spirochetal jaundice. The cause is unknown.

Incubation period. The incubation period of infectious jaundice is usually about six days, but may vary from five to twelve days.

Susceptibility and immunity. The degree to which man is susceptible to infection with *L. icterohaemorrhagiae* has not

been definitely determined. Presumably, man is rather highly susceptible. Immune bodies can be demonstrated in the blood of patients and convalescents, and claims have been made that an immune serum of curative value can be produced by the immunization of horses to the infection. It is not definitely known, however, whether or not an attack of the disease confers permanent immunity to future infections.

Prevalence and importance. Infectious jaundice occurs in all countries, but is most common in Japan and Egypt. The spread of the disease is facilitated by insanitary conditions, especially where there is prolonged contact with wet soil in the presence of crowding and rats. The conditions existing in trench warfare and in wet mines are particularly favorable for the spread of the infection.

During the World War there were 452 cases of spirochetal jaundice reported as occurring among all United States troops. Epidemics of jaundice were reported from all major World War armies, but the proportion that was caused by infection with *L. icterohaemorrhagiae* cannot be determined. British writers state that extensive epidemics of catarrhal jaundice of unknown origin occurred among troops in Mesopotamia, Egypt and Salonika.

Transmission. The causal agent of infectious jaundice is probably transmitted chiefly by water, food, or other substances contaminated with the urine of man or rats. Direct inoculation with soil or other material contaminated with infected urine may also cause infection. The portal of entry may be the alimentary canal or abrasions of the skin.

Control measures. The control of infectious jaundice is based on the correction of sanitary defects which will allow contamination of water and food with the excreta of rats, including measures for the control of rats and the protection of food from contamination by rats (Chapter XIX). Cases of infectious jaundice should be isolated in hospital until they are no longer infectious. The urine and feces should be disinfected prior to disposal.

A vaccine consisting of the killed cultures of the leptospira has been used in Japan to protect against infection.

TRACHOMA

Trachoma is a chronic infectious disease characterized by follicular conjunctivitis with the formation of granulations (trachoma bodies) in the conjunctival membranes and pannus, and the ultimate formation of scar tissue, accompanied by impairment of vision and blindness.

The etiological agent of trachoma has not been definitely determined. The disease is thought by some authorities to be due to inclusion bodies, or a filterable virus, and by others to specific bacteria. Noguchi's work indicates that the microorganism, *Bacterium granulosis*, may be the causative agent. Other authorities consider deficient diet to be in some way concerned in the causation of trachoma.

The infectious agent is contained in the secretions from the eyes and is transmitted from person to person by means of the hands, and by towels, handkerchiefs and other articles used in common by infected and noninfected persons. The disease is communicable as long as the discharges from the eyes persist. At the present time, trachoma is the most prevalent where sanitary conditions are poor and the ordinary rules of personal hygiene are ignored.

Trachoma is of relatively minor importance among American troops. Sporadic cases occasionally occur, but the disease does not tend to spread nor to become endemic.

Control measures. Control measures consist chiefly of those designed to prevent entrance into the service of men who have trachoma and the early detection, isolation and prompt treatment of any cases which might occur among troops. In the care of cases in hospital, measures should be taken to prevent the transmission of the infection to others by means of articles contaminated with discharges from the eyes.

SCURVY

Definition. Scurvy in adults is a deficiency disease caused by subsistence on a diet deficient in the antiscorbutic food factor, vitamin C (*ascorbic acid, cevitamic acid*) (page 422). Typical scurvy is manifested clinically by weakness, anemia, and interstitial hemorrhages which may occur in any of the body tissues, but characteristically involve the gums, skin, muscles,

and the periosteum, especially of the tibia. There may be effusions into the pleural and pericardial cavities with consequent respiratory and cardiac embarrassment.

Pre-scorbutic period. (*Deprivation stage*). Even when vitamin C is entirely removed from the diet, a period of time intervenes before the disease develops. The length of this period varies somewhat with the previous physical condition and with the adequacy of the diet with regard to its vitamin content before deprivation of vitamin C foods began, but, ordinarily, symptoms of scurvy will appear in from two to six months. Where the ration contains vitamin C, but in quantities less than that required for the needs of the body, the amount present may be sufficient to prolong greatly the pre-scorbutic period, and prevent, for the time being, the development of typical scurvy.

The pre-scorbutic condition is manifested principally by loss of weight, lassitude, vertigo and lowered resistance to fatigue. In the more advanced cases, fatigue is accompanied by pain or stiffness in the legs and feet. Frequently, a diarrhea occurs during this stage and there is diminished resistance to infection.

Prevalence and importance. Typical scurvy seldom occurs in modern armies. Except under the most extreme conditions, the ration of American troops always contains sufficient vitamin C foods to prevent the occurrence of clinical symptoms of scurvy. The ration may, however, be deficient in antiscorbutic foods to a degree which will cause the development of pre-scorbutic conditions of greater or less severity with the resulting impairment of efficiency and morale.

Control measures. The development of pre-scorbutic conditions, as well as typical scurvy, is prevented by the inclusion in the ration of an adequate quantity of foods which contain vitamin C (page 422) (Appendix IV). These foods are essentially fresh leafy vegetables, raw fresh fruits, especially citrus fruits, and tomatoes, potatoes, carrots and onions. Tomatoes are particularly useful. They are usually easily obtained and, while the raw vegetable is more desirable as a source of vitamin C, the canned product possesses valuable anti-scorbutic properties.

BERIBERI

Definition. Beriberi is a deficiency disease caused by subsistence on a diet deficient in vitamin B_1 (page 420). Typical beriberi is manifested clinically by an insidious onset, degenerative changes in the nervous system with multiple peripheral neuritis, myocardial degeneration, generalized edema and serous effusions. Where the predominating symptoms are due to changes in the nervous system, the disease is known as *dry beriberi*. Where the most prominent symptoms consist of edema and serous effusions, the condition is known as *wet beriberi*.

Pre-beriberi period (*Deprivation stage*). Total or partial deprivation of vitamin B_1 produces physical impairment, the severity and extent of which vary with the length of the deprivation period and amount of vitamin B_1 in the diet. The pre-beriberi stage is usually characterized by physical weakness which is manifested chiefly by disinclination to stand or to walk. There may be involvement of the myocardium, anemia and slight edematous swelling of the legs.

Where the diet contains no vitamin B_1, definite clinical symptoms of beriberi usually appear in from three to four months after the adoption of the faulty diet. Where the diet contains an inadequate quantity of the vitamin, the pre-beriberi stage may be prolonged or definite symptoms of beriberi may not occur. In some instances, the pre-beriberi condition may be long continued and eventually develop into frank beriberi without change in the diet.

Prevalence and importance. Beriberi occurs endemically in localities where the dietary habits of the people are such that their food consists chiefly, if not entirely, of polished rice, white flour, or other foods deficient in vitamin B_1.

As a disease entity, beriberi is practically unknown among American troops but, unless guarded against by administrative and disciplinary measures, it may occur among native troops of tropical and sub-tropical regions. With native troops, it is not necessarily due to a ration which is lacking in vitamin B_1 as issued, but to the racial dietary habits of the troops which cause them to prefer, and to subsist on, a diet of polished rice to the exclusion of the vitamin B_1 foods contained in the ration.

Beriberi has occurred in native prisons and internment camps, where the prisoners were subsisted on a ration deficient in vitamin B_1 foods.

Pre-beriberi conditions, in which definite symptoms of beriberi do not occur, may prevail among troops subsisted over a comparatively long period of time on a ration which contains less than the required quantity of vitamin B_1. The prevalence and severity of pre-beriberi conditions are determined by the degree to which the ration is deficient in vitamin B_1, and the length of time that the troops are subsisted on such ration.

Control measures. The prevention of beriberi and pre-beriberi conditions depends on the *consumption* of an adequate quantity of vitamin B_1 foods (page 420) (Appendix IV). Not only must the ration as issued contain the necessary vitamin B_1 foods, but messes must be administered in such manner that the troops will eat the articles containing vitamin B_1. The latter factor is of great importance in feeding Filipino and Porto Rican troops, whose pre-existing dietary habits are such that they frequently prefer polished rice as a stable article of diet to other foods which are more desirable, in so far as the vitamin B_1 content is concerned.

TINEA CRURIS
(*Dhobie itch*)

Of the various skin diseases caused by fungi, tinea cruris, or dhobie itch, tends to be the most prevalent among troops serving in the tropics. It is caused by several species of fungi belonging to the genus *Epidermophyton,* but most commonly by *Epidermophyton inguinale.* It may also be due to species of *Microsporum.*

Tinea cruris is characterized by reddened, inflamed and swollen areas which begin as rounded, elevated papules and extend peripherally, producing a raised festooned border covered with scales. The infection is accompanied by intense itching and irritation which is most pronounced at night. Secondary bacterial invasion may occur producing boils and abscesses. The infection occurs most commonly in the perineal region and the adjacent surfaces of the thighs, and in the axillary region. It may spread to the chest and abdomen and frequently occurs between the toes.

The clinical symptoms may disappear during cool weather or when the patient goes to a temperate climate, only to reappear during the next hot season or on return to a hot, moist climate.

Transmission. The causal agent of tinea cruris is transmitted from person to person by contact, chiefly by the hands, clothing, towels or bath room floors. It is possible that the latrine or toilet seat is a factor in the transmission of the fungus. The name "dhobie itch" is derived from the belief that the native washerman (dhobie) infects the clothes with the causal organism. It is not probable, however, that this method of transmission is at all common.

Control measures. Every patient should be thoroughly treated, even though the infection is slight, in order to eliminate him as a source of infection. It may be desirable to hospitalize acute cases, to the end that transmission of the infection to others by contact will be prevented.

All clothing and bedding should be laundered in steam laundries.

Daily bathing and the use of a drying powder after the bath serves to prevent, to some extent, the development of the infection. The powder, which may consist of equal parts of boric acid, zinc oxide and starch, should be dusted on the skin of the perineum and axillae.

RINGWORM OF THE EXTREMITIES

(Dermatomycosis or Epidermophytosis of the hands and feet, Athlete's foot)

Definition. Dermatomycosis, or ringworm of the extremities, is a subacute or an acute inflammatory condition of the skin occurring most frequently on the feet, especially between and on the plantar surface of the toes and on the soles of the feet. It also occurs on the hands, particularly between the fingers, and occasionally on other parts of the body. It is characterized by various types of lesions, including thickening and scaling of the epidermis, excoriation of inflamed areas, fissures and vesicles or blebs. Usually, there is more or less intense itching.

Etiology. Ringworm of the extremities is caused by parasitic fungi. It is generally believed that species of *Epidermophyton* and *Trichophyton gypseum* are the most common causative

agents. The organisms can be destroyed by ordinary disinfectants and by boiling water.

Prevalence and importance. Ringworm of the extremities is one of the most prevalent of all skin diseases, although many cases may pass undiagnosed unless their presence is revealed as the result of special examinations. The presence of this condition in a military organization has an adverse effect on the morale of the troops. Relatively severe infections may incapacitate for the performance of military duties.

Transmission. The causal agents of ringworm of the extremities are usually transmitted by indirect contact through the medium of inanimate objects. The infection is most commonly spread by contact of the bare feet with the floors, mats, benches, etc., in the bath rooms of gymnasiums, clubs and swimming pools. Towels, slippers or shoes, or other articles worn next to the bare skin are frequently incriminated in the transmission of the causative organisms. The primary source of the infection is the infected individual. As far as is known, the organisms are not derived primarily from animals or from the soil.

Control measures. The spread of the infection among troops can be most effectively controlled by the disinfection of bath house floors and equipment and by the sterilization or disinfection of towels, swimming or gymnasium suits, and similar articles by which the infection might be transmitted. Bath house floors and equipment, including mats, benches, chairs, etc., should be scrubbed daily with a disinfectant. A solution of calcium hypochlorite, soap and a hot 1 to 10,000 solution of mercuric chloride, or the various cresol or phenol solutions may be used as disinfectants (page 387). Individual slippers of rubber or other waterproof materials are useful in preventing contact of the bare feet with infected surfaces. All articles that can be boiled should be sterilized by boiling. Leather and rubber goods can be disinfected with a cresol solution. Shoes can also be disinfected by a one per cent solution of thymol in gasoline or alcohol. This solution is poured into the shoe and allowed to drain away or evaporate.

The exchange or common use of towels, gymnasium suits, slippers, gloves, etc., should be avoided or they should be disinfected after use.

The feet of all troops should be carefully inspected at each monthly physical inspection (page 1085) Where it is suspected that any considerable number of cases are present in a command, special inspections should be made for the purpose of detecting mild cases. All cases found should be given adequate treatment. The very mild as well as the more severe infections should be treated in order to eliminate them as sources of infection.

SCABIES
(*Seven year itch, Army itch, Venereal itch*)

Definition. Scabies is an acute inflammatory condition of the skin due to the presence in the epidermis of *Sarcoptes scabiei* var. *hominis*, or itch mite. Simple scabies is characterized by the formation of vesicles and papules accompanied by intense itching which is more pronounced in the presence of warmth. The lesions are most commonly located on the lateral surfaces of the fingers, on the wrists, buttocks, genitals, especially on the penis, and on the elbows, knees and ankles. Scabies may be complicated by secondary infection with the production of an ecthymatous impetigo, boils, or dermatitis.

Etiology. Scabies in man is practically always due to *Sarcoptes scabiei* var. *hominis*, and is seldom caused by any of the several species of Sarcoptes which infest animals. The itching and irritation are caused by an acrid fluid which the parasites secrete in the skin, while the secondary pyodermia results from scratching by the host.

Sarcoptes scabiei var. *hominis* belongs to the order Acarina, which includes the ticks and mites. The female is from 0.3 to 0.4 mm. and the male about 0.2 mm. in length. The impregnated female burrows into the epidermis, creating tunnels one-sixteenth inch to one-fourth inch or more in length. The burrows do not penetrate into the tissues below the epidermis. The eggs are deposited in the burrow.

The eggs hatch in from four to five days. The larval and nymphal forms pass through four stages to become adults in about two weeks. The larvae also bore into the skin to find protection and food. The males and newly matured females are to be found under the scales and crusts on the surface of the skin.

The female lives for from three to five weeks and deposits from 25 to 50 eggs. It is probable that the female dies in the burrow, although she may live for a week or longer, and deposit ova, when separated from the body of the host.

The activity of the mites is governed to a very considerable extent by the warmth of the skin. Active burrowing takes place when the skin is warm and ceases when it is cold.

Prevalence and importance. Scabies is more prevalent under insanitary conditions, especially where there is excessive crowding, lack of bathing facilities, and where the underclothing must be worn for long periods of time without changing or cleaning. Consequently, scabies is most prone to occur among troops under combat conditions, although it also occurs in other situations where poor sanitation facilitates its spread.

During the World War, there were 8.38 admissions for scabies per 1000 strength among all troops. The admission rate among enlisted men in the United States was 5.54 per 1000 strength as compared with 13.30 per 1000 strength among the enlisted men in Europe. The prevalence of scabies in the army during the years of 1933, 1934 and 1935 is shown in the following table:

Admission for scabies among all troops, United States army, during the years 1933, 1934, 1935, inclusive.

Rates per 1000 strength per annum.

Year	Rate per 1000
1933	7.2
1934	7.3
1935	5.5

Scabies is an important condition from a military viewpoint because of its adverse effect on the morale and efficiency of the individual. Further, each case of uncomplicated scabies entails a loss of time from duty of at least three or four days, while scabies complicated by pyodermic conditions will frequently necessitate hospitalization for several weeks.

Transmission. The source of infestation with *Sarcoptes scabiei* is the person with scabies. The parasite is transferred by direct body contact and by close indirect contact through the

medium of clothes and blankets. The clothing of persons who have had scabies may remain infested and capable of transmitting the parasite for at least eleven days.

While scabies is sometimes known as "venereal itch", it is a venereal disease only in the sense that the parasite may be transmitted as the result of body contact during sexual intercourse.

Control measures. Scabies among troops, and its spread from infested recruits or isolated cases, is controlled by personal hygiene measures which promote general body cleanliness, by cleanliness of clothing and blankets, and by preventing undue crowding. The control or eradication of existing infestation is accomplished by proper diagnosis, disinfestation of the skin, and disinfestation of the clothing and blankets.

Diagnosis. Correct and prompt diagnosis is of paramount importance in the control of scabies. In the presence of pediculosis, the irritation of the skin and the accompanying pyodermic conditions are frequently regarded as due to lice, and the possibility of infestation with scabies is forgotten or ignored. The measures employed for the eradication of lice from the body are not effective against scabies, and, consequently, under these circumstances, a missed case of scabies continues to be a source of infection.

On the other hand, when scabies is known to be present in a command, there is frequently a tendency to consider all cases of skin irritation as scabies, even though the conditions in question may be due to other causes, such as pediculosis, or skin infections of various kinds. The measures employed in the treatment of scabies may produce a dermatitis and will, in any event, result in the patient being absent from duty for at least three or four days. Treatment should not, therefore, be given unless scabies is actually diagnosed.

The diagnosis of scabies is based on evidence of the presence of the parasite in the skin. In uncomplicated scabies, the burrows made by the parasite in the epidermis can be readily seen as fine raised tortuous lines. The vesicle appears at the end of the burrow as a small glistening spot about the size of a pin head. The presence of typical burrows and vesicles is pathognomonic of scabies, but the diagnosis should be confirmed by the detection of the parasite in the burrow.

Usually, scabies is complicated by pyodermic conditions which obscure the burrows and render the detection of the para-

site difficult. As a rule, however, the parasite can be found if sufficient time is given to the inspection of the skin. Frequently, a hand lens will prove to be a valuable aid in finding the parasites.

The location of the lesions between the fingers, on the wrists, or on the genitals, elbows or knees, while not necessarily diagnostic, serves to differentiate scabies from scratch marks and irritation due to bites of body lice.

Disinfestation of the skin. The disinfestation of the skin can be accomplished only by treatment which will destroy all forms of the parasite. In practice, this treatment consists of thorough bathing with hot water and soap to remove the crusts and scales, followed by the application of an insecticide. Green soap should be used and the entire body should be thoroughly scrubbed for from ten to fifteen minutes with a coarse bath mit. A bath mit made of turkish toweling or similar cloth may be used, or nail brushes may be employed, especially in scrubbing the extremities. The soap should then be removed with hot water and the body thoroughly dried. Sulphur ointment (USP) is then applied over the entire body, from the neck to the tips of the fingers and toes, and thoroughly rubbed in. This treatment is repeated on the following day and, in the more heavily infested cases, on the third day. A cleansing bath is then given and the patient is regarded as cured, if no evidence of the insect can be found.

Liquor calcis sulphuratae (lime and sulphur lotion, Vleminck's solution) may be used in lieu of the sulphur ointment. Sulphur ointment containing ten per cent of balsam of Peru may be used in the treatment of complicated cases. The itching may continue for some time after treatment and does not necessarily indicate that the treatment has failed to effect a cure.

Occasionally, the treatment may cause sulphur dermatitis. A pyrethrin or rotenone ointment may be used instead of sulphur, especially in the treatment of individuals subject to sulphur dermatitis.

As none of the insecticides will destroy the eggs, it may be necessary to repeat the treatment in about a week.

Disinfestation of clothing and blankets. The clothing and blankets of men having scabies should be disinfested by the methods employed for delousing (page 960). Care should be

taken that all articles of clothing, including gloves and shoes, are disinfested.

Segregation of patients. All troops undergoing treatment for scabies should be segregated in group quarantine until the treatment is completed (page 23). Where practicable, men who have received the treatment should be reinspected after ten to fourteen days have elapsed subsequent to completion of the treatment for evidence of infestation due to failure of the treatment to destroy all the parasites.

RABIES
(*Hydrophobia, Lyssa*)

Definition. Rabies is an acute infectious disease of animals, which is communicable among animals, and from animals to man, by inoculation. It affects the central nervous system and in man is characterized by nervous excitement, localized spasms, especially of the muscles of deglutition and respiration, convulsions and paralysis. It is always fatal.

Rabies infection is primarily an infection of the nerve fibers. The virus passes slowly along the nerve trunk to the brain, where invasion of the nerve cells produces the characteristic symptoms of the disease. The function of the nerves is not impaired by the passage of the virus.

Rabies may occur in any mammal, but is most prevalent among dogs. In the dog, the disease occurs in two general forms—furious rabies and dumb or paralytic rabies. The furious type is characterized by three stages, the prodromal stage, the stage of excitement, and the paralytic stage. In most instances, excitement is not present in the dumb form of the disease. During the prodromal stage there is usually a marked change in disposition and the animal becomes nervous and restless.

In the *furious type,* the stage of excitement is prolonged and is characterized by a tendency to wander or run wildly for some distance away from home. During this stage, the dog snaps at or bites any nearby object, person, or animal. Owing to the difficulty of swallowing, the saliva drops from the jaws. The bark is changed and may become a coarse, low howl. The stage of excitement gradually merges into the paralytic stage. Weakness usually develops first in the hind quarters and extends

to the forelegs and lower jaw. In some instances, the muscles of the jaw are the first affected.

In dumb or paralytic rabies, paralysis or muscular weakness may be the first symptom detected. In many instances, weakness of the muscles of the jaw (*dropjaw*) is the first manifestation of the disease in the dog.

Many animals present mixed symptoms, but the furious type predominates in about 80 to 85 per cent of the cases in dogs.

An attack of rabies in the dog usually lasts for from four to eight days and is practically always fatal.

Etiology. Rabies is due to a filterable virus which is present in the central nervous system, various tissues of the body and in the salivary glands, especially the submaxillary glands. The infection of the central nervous system is accompanied by the formation of Negri bodies. These are round or oval granules or bodies which vary from one to twenty-seven microns in diameter. Negri bodies are most abundant in the ganglion cells of Ammon's horn (hippocampus) but are also present in the Purkinje and pyramidal cells, in the cerebral cortex and cerebellum, and in the nerve cells of the spinal cord.

Negri bodies are characteristic of rabies and various theories have been advanced relative to their relation to the causative virus. It is held by some authorities that the minute chromatin-masses within the Negri body are the causative agents and that the outer mass is formed by the reaction of the infected cell. Others are of the opinion that Negri bodies are formed by the reaction of the cell to the rabies virus but that the bodies do not necessarily contain the virus.

Rabies virus is quickly destroyed by nitric acid or formaldehyde, but is highly resistant to glycerin. It is destroyed by 1:1000 solution of mercuric chloride in about an hour. It is also destroyed by exposure to a temperature of 58°C. for 30 minutes. Its virulence is not decreased by freezing. Rabies virus retains its virulence when rapidly dried at any temperature below 96.8°F. (36°C.). Slow drying at room temperature (about 68°F.) causes a gradual reduction in virulence.

Incubation period. The incubation period of rabies in man is variable, but is usually from two to eight weeks. The average is about forty days in adults. It may, however, be prolonged to more than six months, but is rarely longer than three months. The incubation period is shorter when infec-

tion occurs in the nerve trunks of the face. It is also shorter in children.

The incubation period in animals is likewise variable. The average incubation period in the dog is from two to eight weeks, but may be as short as eight days or as long as one year. It may be somewhat shorter in cats and longer in cattle and horses.

Susceptibility. The susceptibility of man to rabies is apparently a variable condition and is modified by a number of factors. Man is probably less susceptible than any of the lower animals. Statistics indicate that, in general, from 15 to 20 per cent of persons bitten by rabid dogs develop the disease. However, the disease occurs in from 50 to 60 per cent of those who are bitten about the face. The most virulent wounds are inflicted by the wolf, cat and dog in the order named.

Animals also possess a variable degree of resistance to infection with rabies. About 50 per cent of laboratory animals will develop the disease following subcutaneous injection of the virus, and about 90 to 95 per cent can be infected by injection into the muscles on both sides of the spinal column. Subdural or intracerebral injection of the virus will always produce the disease. About 40 per cent of the dogs bitten by rabid animals develop the disease.

Sex and race apparently have no influence on susceptibility. Children are more susceptible than adults.

Prevalence and importance. The prevalence of rabies among the human population of a community is entirely dependent on the prevalence of the disease among animals, and on the opportunities for rabid animals to transmit the infection to man. Consequently, the incidence of the disease varies greatly in different countries of the world. The disease is wide spread among dogs in the United States. It is also prevalent in the Orient. It is rare in England and in Northern Europe generally, except in Russia. It does not occur in Australia.

The season of the year has no direct influence on the spread of rabies. The disease is more prevalent in the summer due to the fact that dogs exhibit a greater tendency to roam during the warmer weather, with a consequent increase in opportunities for them to be infected. Hot weather *per se* does not enhance the susceptibility of dogs to infection.

Transmission. Because of its habits and its close association with man, the dog constitutes the most common source of infection from which rabies is transmitted to man.

In the United States, about 85 per cent of the cases of rabies among animals occur in dogs. While the disease occurs in cats, wolves, coyotes, foxes, ground squirrels, rats, horses, cattle, sheep and swine, these animals are not common sources of infection for man.

The virus of rabies is transmitted by inoculation of saliva through a wound or an abrasion of the skin or mucous membrane. Usually, the infected saliva is inoculated by biting, but inoculation not infrequently results from licking of the hands or other parts of the body by a rabid animal. Infection may also result from handling a sick animal. The virus will not pass through the unbroken skin or mucous membrane, and an abrasion, cut or wound must be present before inoculation of the infected saliva is possible.

The rabies virus is not transmitted by the ingestion of contaminated food or drink. While, theoretically, rabies could be transmitted by the saliva of the infected person, actually such transmission never occurs. Neither is the infection transmitted by contaminated fomites, although transmission in this manner would be possible.

The infection is communicable by the dog, or other animal, from as long as seven days before the appearance of symptoms throughout the course of the disease until death occurs.

Control measures. The prevention of rabies in man is based on the prevention of the disease among dogs, the treatment of the wound, and prophylactic treatment to prevent the development of the disease.

Prevention of rabies among dogs. With rare exceptions, the prevalence of rabies is maintained in any locality by the infection of dogs and its eradication or ultimate control is entirely a question of controlling its spread among dogs. The measures employed for this purpose consist of the extermination of all stray or ownerless dogs, strict supervision of owned dogs, muzzling or restraint, and vaccination.

Vaccinated dogs show a relative increase in resistance to rabies, but vaccination occasionally fails to confer protection against infection. Either carbolized or chloroform-treated vac-

cine is used for the vaccination of dogs, but, generally, better results have been obtained with the chloroform-treated vaccine. Ordinarily, one dose of the vaccine is administered and repeated at yearly intervals. Experiments recently made by Webster and others with vaccine derived from tissue culture virus have yielded promising results.

Where rabies is present in a community all dogs owned by persons living on an army post should be vaccinated once each year. A metal tag showing the year the vaccine was administered should be attached to the collar of the dog. A certificate describing the dog and giving the date of vaccination should be given to the owner of the dog and a duplicate filed in the office of the post surgeon.

When a case of rabies occurs among animals on or near a military post, all dogs on the post should be vaccinated with antirabic vaccine and kept muzzled or on leash until one month after the termination of the last case.

Where dogs cannot be vaccinated, any dog exposed or suspected of being exposed to infection with rabies should be destroyed or held in quarantine for at least six months. Under similar circumstances, where rabies occurs among animals on or near a military post, all dogs on the post should be kept on leash or muzzled until 90 days after the termination of the last case.

Treatment of wound. The virus inoculated into the bite wound may be destroyed and the disease prevented by thorough disinfection of the tissues. *Fuming nitric acid*, because of its diffusibility and penetration, is the most effective disinfectant for this purpose. The wound or wounds should be opened to the bottom and all lacerated tissues removed. The wound should be thoroughly cleansed with one of the usual disinfectant solutions. Free bleeding should be encouraged. Every part of the wound, including all pockets and recesses, should then be thoroughly cauterized with the fuming nitric acid applied, preferably, with a glass rod. A general anesthetic may be given if necessary. As a rule, cauterization with fuming nitric acid does not produce any considerable amount of additional scar tissue if the acid is properly applied.

If fuming nitric acid is not available, the concentrated nitric acid (approximately 68 per cent) should be used. Formaldehyde is also effective when used in the same manner as the nitric acid. Pure carbolic acid may be used in lieu of nitric acid or

formaldehyde, but is not as effective. The ordinary disinfectants, such as iodine or the phenol solutions, are of little or no value.

The wound should be treated as soon as possible after infection, preferably within twelve hours, but treatment with fuming nitric acid is of value even when applied as late as forty-eight hours after exposure.

Prophylactic treatment (*antirabic vaccination*). Prophylactic treatment against rabies in man is based on the production of active immunity by the administration of a specific vaccine subsequent to the inoculation of the virus. Prevention by post-exposure vaccination is rendered possible by the long incubation period, which is due to the slow passage of the virus along the nerve fibers. The disease does not develop until the virus reaches the brain.

Street virus is rabies virus which is transmitted from animal to animal and from animal to man by natural means and which will cause rabies. When street virus is passed through a series of rabbits by successive subdural injections of infected material from the central nervous system, there is a gradual increase in virulence for the rabbit and a consequent gradual decrease in the length of the incubation period. Eventually, the virus will regularly produce symptoms in a rabbit after an incubation period of from seven to eight days. This virus is known as "*fixed virus*".

Several methods have been developed for the production and administration of antirabic vaccine. In the original and classic Pasteur treatment, the vaccine is made from the dried spinal cord of a rabbit infected with the fixed virus. The completely paralyzed rabbit is killed on or shortly after the seventh day and the cord is dried at 25°C. (77°F.) over caustic potash for a successive number of days. Spinal cord material is thus obtained which has been dried for from one day to fourteen days, or in the modified method as used at the present time, from one day to six to eight days. A dose of the vaccine consists of approximately one-half centimeter of the cord emulsified in 2.5 c.c. to 3 c.c. of sterile salt solution, and is injected subcutaneously. Different procedures are followed in the administration of the Pasteur treatment. Usually, the first dose consists of cord which has been dried for from six to eight days. Daily, or twice daily, injections are made for twenty-one days, using cords which have

been dried for a shorter time until one-day or two-day cord vaccine is being injected. The dosage is less in children and is increased when the bites are multiple or are on the face.

The production of the vaccine by the Pasteur method is expensive and time consuming and the vaccine must be shipped and preserved at low temperatures. Further, the dosage is difficult to control. Consequently, other methods have been devised which will produce a more stable vaccine and one which can be more easily administered than the Pasteur vaccine. Of these modified methods, the Semple method is most widely used in the United States at the present time.

The *Semple vaccine* is made from the brain and medulla of rabbits infected with fixed rabic virus. This material is ground in sterile salt solution containing one per cent carbolic acid, strained through finely woven cloth, and kept at 37°C. for twenty-four hours. This treatment kills the virus, or attenuates it so that it will not produce rabies when injected into rabbits. The vaccine is then diluted with salt solution so that the final product contains four per cent of the vaccine material and 0.5 per cent carbolic acid.

The Semple vaccine is administered by subcutaneous injection into the abdominal wall. Usually, one dose of two to four c.c. is given each day for fourteen days. The dosage is not ordinarily varied because of age, sex or the character of the wounds. A more intensive or a longer course may be given where there are extensive wounds on the face.

The Semple vaccine will keep for several months when stored at ordinary or ice box temperatures and can be shipped by ordinary mail. It is more easily manufactured than the Pasteur vaccine and is much less costly. As compared with the Pasteur vaccine, the Semple vaccine is easier to administer and there is less chance of error. Studies have shown that the treatment with the Semple vaccine is as effective in preventing the development of rabies as the classic Pasteur treatment, and there is less danger of post-treatment paralyses (*infra*). Because of these features, the Semple method of prophylactic treatment is the method of choice for use in the army.

Other prophylactic treatment methods include the *Hoyges method* and the *Harris method*. In the Hoyges method, the vaccine consists of diluted suspensions of fresh fixed virus. The

treatment consists of twenty-four injections which vary in strength from 1:10000 to 1:100.

In the Harris method, the infected material is desiccated at low temperature with the result that full virulence is retained. The vaccine thus produced is sufficiently stable to permit accurate standardization of dosage by units, a unit being the amount which, when injected into the brain of a rabbit, will produce paresis on the seventh day. The number of doses constituting a treatment varies according to the character and location of the wounds.

Webster and other workers have shown that rabies virus can be propagated in tissue culture of mouse embryo brain, and that, under the experimental conditions, antirabic vaccine made from tissue culture virus will produce a high degree of protection against the street virus.

Reactions to prophylactic treatment. Reactions to antirabic vaccine are not usually severe. As a rule, there is a local reaction consisting of erythema and tenderness. There may be a slight general reaction manifested by fever and malaise.

Paralysis may occur as a complication of antirabic vaccination. The incidence of post-vaccinal paralysis has varied greatly in the different series that have been reported, but it is probable that the average incidence is about one case among every 3000 to 4000 persons receiving the prophylactic treatment. It usually occurs in adults and seldom affects children. The onset of paralysis may occur as early as the sixth day or be delayed to as late as the twentieth day after the beginning of the treatment. Post-vaccinal paralysis varies in extent and severity and may terminate in recovery, partial recovery or death. The death rate among those who develop paralysis is about 15 per cent.

Results of prophylactic treatment. The development of the rabies is prevented by prophylactic treatment only when the immunity conferred is sufficient to kill the virus inoculated by a bite, or otherwise, before it reaches the brain. In the presence of severe wounds, especially if the wounds are on the face, head or neck, a delay of as much as ten days in beginning prophylactic treatment will, as a rule, preclude the development of immunity in time to prevent the disease.

As a general rule, immunity is not produced until at least fourteen days after the completion of the prophylactic treatment. Consequently, where rabies develops prior to fifteen days after

the completion of the treatment, the prophylactic treatment was not begun in time. Where the disease develops subsequent to fifteen days after the completion of the prophylactic treatment, the treatment has failed to protect. Calculated on this basis, a large number of studies show that prophylactic treatment fails to protect only in from 0.12 to 0.7 per cent of cases.

The immunity conferred by one prophylactic treatment probably lasts only for a relatively short time. Where a person is again bitten after receiving prophylactic treatment he should be given another treatment.

Indications for prophylactic treatment. It is sometimes difficult to determine whether or not a person who has been bitten by a dog should be given the prophylactic treatment. The decision as to whether or not prophylactic treatment should be given must be made in accordance with the conditions under which the biting occurred. Usually, as explained below, laboratory examinations are of little assistance in making this decision. The treatment should be given in every instance where there is the slightest chance that a person has been infected with rabies virus. Failure to give the prophylactic treatment is justified only when the wound is accidentally inflicted by a known dog under conditions which render it unlikely that the dog is rabid.

Wherever possible, the dog should be captured and restrained by chaining for 15 days. If no symptoms develop during the 15 day interval, it is safe to assume that the dog was not rabid at the time of biting and prophylactic treatment which has been started can with safety be discontinued. If the dog develops rabies, or if it dies from any cause during the 15 day interval, the treatment should be completed. If the dog escapes capture, a complete prophylactic treatment should be given the bitten person.

If the dog is killed at the time of biting, or is killed or dies during the 15 day interval of restraint subsequent to biting, the head or the entire carcass should be sent to the nearest army or civilian laboratory for examination for Negri bodies. Prophylactic treatment should not, however, be delayed until the receipt of the laboratory report and failure to find Negri bodies does not justify discontinuance of prophylactic treatment. If no Negri bodies are found, rabbits or guinea pigs should be inoculated with an emulsion of the brain substance, usually of the medulla oblongata. The incubation period in laboratory animals is from twelve days to several weeks, usually under twenty days. Failure

of the inoculated animals to develop rabies is regarded as conclusive evidence that the dog was not rabid. However, the results obtained by the inoculation of experimental animals are not, in most instances, available prior to the completion of the prophylactic treatment of the bitten person.

The prophylactic treatment should always be given to persons who have been bitten by wolves, coyotes or by other animals under conditions which justify the least suspicion that such animals are rabid.

Antirabic vaccine may be obtained in the usual manner by requisition on the proper supply agency. In an emergency, the vaccine can be secured from or through the health department of any state in which rabies occurs.

Concurrent disinfection. In the treatment of rabies patients in hospitals, particular attention should be devoted to the disposal of the sputum and the disinfection of articles contaminated with sputum. Attendants should exercise special care to avoid contact with the sputum of the patient.

TETANUS
(*Lockjaw, Trismus*)

Definition. Tetanus is an acute infectious disease characterized clinically by toxemia which affects the central nervous system and is manifested by painful, tonic spasms of the muscles accompanied by acute exacerbations. As a rule, the muscles of the jaw and neck are the first to be affected. In severe cases, any of the voluntary muscles may be involved.

Tetanus may occur in a modified or local form when the course of the disease is modified by the administration of prophylactic tetanus antitoxin. The clinical course of modified tetanus is atypical and manifested chiefly by local tonic or clonic spasms in the region of the wound, occasionally trismus in some degree and opisthotonos. The incubation period is usually prolonged and symptoms may occur weeks or months after infection. The mortality in local tetanus is relatively low, as compared with acute or general tetanus, but there is a marked tendency to chronicity.

Etiology. Tetanus is caused by the tetanus bacillus (*Clostridium tetani*) and, in almost all cases, by the inoculation of the spores into a wound where the vegetative forms develop and

multiply. The tetanus bacilli excrete a true soluble exotoxin which has a specific affinity for the central nervous system and is the immediate causative agent of tetanus.

The tetanus bacillus has its natural habitat in the intestinal tract of animals, especially the herbivora, and is excreted in the feces. It also occurs in the digestive tract of man, and chronic human tetanus carriers are not uncommon. Neither the tetanus bacillus nor its toxin will produce the disease when ingested, although possibly ingested spores may find their way into small wounds in the walls of the digestive tract. The ingested spores are not destroyed by gastric secretions.

Deep penetrating wounds, or wounds in which there is extensive laceration of the tissues, present particularly favorable conditions for the growth of tetanus bacilli. Infection with pyogenic organisms, especially in the presence of devitalized tissue, apparently favors the development of the tetanus bacilli.

It is generally believed that the toxin produced by the organisms growing in the wound reaches the central nervous system in the circulating blood and by absorption along the motor nerves. Tetanus antitoxin does not affect the ability of the organisms to grow in the infected tissues, but it does neutralize the toxin in the blood and lymph, and thus shields the higher nerve centers. The antitoxin does not, however, prevent the absorption of the toxin by the local motor nerve endings, and the consequent development of modified tetanus or local spasticity.

The vegetative form of the tetanus bacillus is readily destroyed by any of the ordinary disinfectants. It is a strict anaerobe and does not survive in the vegetative form when exposed to air. The spores are, however, exceedingly resistant and can survive exposure to a temperature of 176°F. (80°C.) for at least one hour. They can resist a dry temperature of 212°F. Actual immersion in boiling water will destroy them in about five minutes. Articles contaminated with the spores of tetanus bacilli can, however, be effectively sterilized by direct exposure for twenty minutes to dry heat at 160°C. (320°F.) or steam at 120°C. (248°F.).

Tetanus spores are killed in two hours by five per cent carbolic acid containing 0.5 per cent of hydrochloric acid, and in thirty minutes by 1:1000 solution of mercuric chloride containing 0.5 per cent of hydrochloric acid. The spores are killed in

about one minute by a one per cent solution of silver nitrate and in about five minutes by a 0.1 per cent solution.

Tetanus spores will live for years in the soil. They are resistant to drying and may be carried for long distances in wind blown dust.

Incubation period. The incubation period of tetanus is variable, but averages from seven to ten days among battle wounded. It may be as short as four days or as long as five weeks or longer. The incubation period may be prolonged in mild or atypical cases and in cases where the course of the disease has been modified by the administration of prophylactic antitoxin.

Susceptibility and immunity. Theoretically, man is universally susceptible to the toxin produced by tetanus bacilli growing in the tissues. Actually, there is considerable evidence that many persons possess a certain degree of acquired immunity. It has been found that carriers of the organisms frequently have the antitoxin in their blood.

Prevalence and importance. Potentially, tetanus is a most important disease from a military viewpoint because of the fact that it is a wound infection. Under modern conditions, however, the incidence of the disease is minimized by the routine use of tetanus antitoxin in the treatment of the wounded.

During the World War, 36 cases of tetanus occurred among 224,098 wounded in the American army, or 0.16 cases per 1000 wounded. This low incidence of tetanus is undoubtedly due to the universal and early administration of tetanus antitoxin.

In the British army, there were 2,549 cases of tetanus among 1,997,199 wounded, a rate of 1.27 per 1000 wounded. Tetanus antitoxin was not administered routinely to British wounded during the first two months of the war, with the result that the incidence rate rose to 8.8 cases of tetanus per 1000 wounded in September, 1914. When orders were issued that the antitoxin would be used, the rate fell to 1.4 cases per 1000 wounded in December, 1914.

Transmission. Tetanus infection is acquired by inoculation into a wound of soil or other material contaminated with animal excreta containing the spores of tetanus bacilli. In the great majority of instances, the contaminated material con-

sists of earth, although many other substances may serve to carry the organisms into the wound. The spores may be inoculated into the depths of a wound by penetrating instruments, such as splinters of wood, or sharp pieces of metal.

Control measures. The control of tetanus depends primarily on the administration of tetanus antitoxin as a prophylactic. Wound excision, or *debridement*, may be of value as a control measure in removing the focus of infection. Ordinary disinfectants will not destroy the spores in the tissues.

Administration of tetanus antitoxin (*passive immunization*). Tetanus antitoxin (antitetanic serum) should be administered by subcutaneous injection in all cases of wounds or injuries in which there is a possibility that material contaminated with tetanus spores might have been carried into the wound. The usual dose is 1500 units. As tetanus antitoxin is rapidly eliminated, a second·dose should be given after seven days have elapsed, unless the wound or other injury is entirely healed. Additional doses should be administered in the case of severe wounds, or in the event of secondary operations on wounds, manipulations of injured joints or of fractures, or when adherent drains are removed from wounds.

The antitoxin should be administered as soon as practicable after the wound or injury is incurred. When administered at aid stations, or at any point in front of the hospital station, a T should be painted with iodine on the forehead to indicate that the antitoxin has been given. The date of administration and the dosage should, in each instance, be recorded on the emergency medical tag or in other medical records of the case.

Active immunization. An anatoxin (toxoid) has recently been developed which promises to provide a practical method of conferring active immunity against tetanus. Both plain and alum precipitated tetanus toxoid have been used experimentally with good results.

Ramon and Zoeller found that the plain toxoid should be administered by three subcutaneous injections of 1.0, 1.5 and 2.0 c.c. respectively, and that there should be an interval of one month between the first and second and one week between the second and third injections. The most effective method of administering the alum precipitated toxoid has not as yet been determined. Some workers believe that it should be given in one dose, others that three doses at weekly intervals, or two doses separated by an

interval of six weeks to two months, will produce the best results.

The studies that have been made indicate that antitoxin develops slowly following the injection of tetanus toxoid, and that several months elapse before the immunized individual is fully protected. There is considerable experimental evidence that a stimulating dose of the toxoid administered several months subsequent to the primary injection, or course of injections, will produce a rapid increase in the amount of antitoxin in the blood.

Tetanus toxoid cannot be used instead of tetanus antitoxin to protect against tetanus at the time of injury, if the individual to be protected has not been previously actively immunized with the toxoid. Theoretically, where the injured person has been actively immunized with the toxoid, an additional injection of the toxoid at the time of injury would protect against tetanus.

There is also experimental evidence indicating that if an individual who has been immunized by one injection of tetanus toxoid is subsequently infected with tetanus bacilli, he will develop sufficient antitoxin to protect him against the disease without additional injections of the toxoid.

ANTHRAX

(Woolsorter's disease, Malignant pustule, Charbon)

Definition. Anthrax is an acute infectious disease of herbivora, principally cattle, sheep and horses. It is communicable to man in whom it occurs in three forms—cutaneous, pulmonary and intestinal. Cutaneous anthrax is usually manifested by the formation of a malignant pustule on an exposed portion of the body, most commonly on the shaving area of the face or neck. The lesion consists at first of a small papule which soon becomes a vesicle containing a brownish fluid. A dark brown eschar develops which is surrounded by small vesicles and a reddened, edematous area. The lymph glands draining the infected area become involved with the production of a painful adenitis. The systemic symptoms are relatively mild, except late in the course of severe infections.

The cutaneous form may occur as malignant anthrax edema which is characterized by a spreading edema. The typical eschar is usually absent, but may develop from vesicles which form on the surface of the edematous area.

Pulmonary anthrax (*woolsorter's disease*) is caused by the inhalation of the spores of anthrax bacilli (*infra*) and is characterized by involvement of the entire respiratory tract. It is usually fatal.

Intestinal anthrax is the form that occurs most frequently in animals but is relatively rare in man. It is characterized by gastro-intestinal symptoms consisting chiefly of nausea and persistent vomiting, diarrhea and severe epigastric pain. Death usually results from this form of infection.

Etiology. Anthrax is caused by *Bacillus anthracis.* In the presence of free oxygen, anthrax bacilli produce highly resistant spores which remain viable in an adverse environment for long periods of time. They are not destroyed by sunlight or drying, or by ordinary disinfectants. They are killed in ten minutes by boiling water and in from five to ten minutes by steam. They are destroyed in three hours by dry heat at a temperature of 140°C. (284°F.). A five per cent solution of formalin will kill anthrax spores in about one hour. A twenty per cent solution will kill them in about ten minutes. Anthrax spores may survive for a number of days in a five per cent solution of carbolic acid.

The vegetative organisms are excreted in the feces and urine of infected animals. Outside the animal body, the organisms form spores which, because of their resistant nature serve to render the contaminated soil or herbage infectious for months and years.

The vegetative forms are destroyed by ordinary disinfectants. They are killed in one minute by a temperature of 80°C. (176°F.).

Incubation period. The incubation period of anthrax is variable, but is generally considered to be less than seven days, probably from one to three days.

Susceptibility and immunity. Man is apparently universally susceptible to anthrax. It is generally believed that one attack confers immunity against future infections.

Prevalence and importance. Anthrax is essentially an occupation disease and occurs most frequently among workers who handle the skins, hair or carcasses of animals. From a military viewpoint it is a disease of minor importance.

There were 149 admissions to hospital for anthrax among American troops during the World War. Sporadic cases occur from time to time among troops during peace.

Transmission. The transmission of anthrax to man is, in most instances, by accidental inoculation resulting from contact with infected hair, skins, wool or carcasses of infected animals. The organisms may, however, be inhaled or ingested and produce either pulmonary or intestinal anthrax.

In most of the cases that have occurred among troops, the infection has, presumably, been transmitted by shaving brushes made from imported hair.

The infection is seldom, if ever, transmitted from person to person.

Control measures. The control of anthrax is in general dependent on the control of the disease among animals and the disinfection of all skins, hair or wool imported from infected districts. The inspection and disinfection of materials imported from abroad into the United States is carried out under the supervision of the United States Bureau of Animal Industry.

Shaving brushes may be disinfected by immersion for four hours in a ten per cent solution of formalin at a constant temperature of not less than 110°F.

The carcasses of all animals found to have anthrax should be incinerated.

GRANULOMA INGUINALE

Definition. Granuloma inguinale is an infectious disease which is characterized by granulomatous ulceration involving most commonly the inguinal regions, genitals, thighs, perineum and anus.

Granuloma inguinale must be differentiated from lymphogranuloma inguinale, which is a separate disease entity (page 1004).

Etiology. The etiological agent of granuloma inguinale has not been definitely determined. In most instances, organisms known as Donovan bodies are to be found in the ulcers. Several studies have been made the results of which indicate that Donovan bodies are bacilli belonging to the aerogenes group.

Incubation period. The incubation period is not definitely known, but, apparently, it is usually from two weeks to a month. More rarely, the incubation period may be as short as one week or as long as three months.

Importance and prevalence. Granuloma inguinale appears to be more prevalent among women than among men, and occurs more frequently in negroes than in members of the white race. The disease is more prevalent in the tropics and occurs sporadically in the southern part of the United States. Relatively few cases have been reported as occurring among American troops.

Transmission. It is generally believed that granuloma inguinale is transmitted by more or less direct contact, and, in some instances, the infection is probably transmitted by sexual intercourse. There is some evidence that the infection is transmitted in fecal material containing the etiological agent.

Control. The prevention of granuloma inguinale in the individual instance depends on cleanliness and on avoiding contact with the infectious lesions. There are no specific control measures. The patient having the disease should be isolated and measures should be taken to prevent the transfer of the infection by contact.

CHAPTER XXVI.

SANITARY SURVEYS AND SANITARY ORDERS

A sanitary survey is an analysis of the conditions existing in a community which exert a favorable or an unfavorable influence on the health of the inhabitants. The primary purpose of any sanitary survey, regardless of its nature or scope, is to secure information or data which will serve to indicate the most practical means by which disease may be controlled or prevented, or the general health conditions improved.

Sanitary surveys vary widely in their scope and character and in the purpose for which they are conducted. A sanitary survey may consist of a general and more or less complete study of all the conditions within a community which actually or potentially affect health. It may, on the other hand, be limited in scope and restricted to the consideration of some specific factor.

A limited sanitary survey is usually made as indicated by the existing health situation for the purpose of controlling or preventing the occurrence of some particular disease or diseases. Such a survey may, for example, be made of a water supply system, where it would have for its objective the detection and correction of conditions affecting the potability of the water and the control or prevention of intestinal diseases. Epidemiological studies are likewise limited sanitary surveys. The methods of conducting limited sanitary surveys dealing with the different phases of the sanitary environment, such as water supply, insect control, housing, or waste disposal, have been considered in previous chapters.

General sanitary surveys. No two communities are exactly alike with respect to those conditions which affect the health of the inhabitants, but all possess certain basic features. Con-

sequently, a general sanitary survey of any community, either military or civilian, includes consideration and study of these basic features which may be classed as follows:

a. Economic conditions.

b. Social factors.

c. Environmental factors.

d. Prevalence of disease.

In a military station, or in a tactical command in the field, the funds available and the policies under which funds are expended for the prosecution of sanitary measures correspond to the economic factors governing the execution of sanitary measures in a civilian community. The discipline and training of troops, together with their racial characteristics, the recreational facilities provided for their use, and the living conditions with respect to housing, food, and work are comparable in general to the social conditions which must be considered in the sanitary survey of a civilian community.

As discussed in Chapter I, a military population differs in certain fundamental respects from a civilian population and the environment of a military organization may be vastly different from that of the surrounding civilian communities. Nevertheless, any post or camp is an integral part of the general community within which it is situated and a complete general sanitary survey cannot, therefore, be restricted to the station concerned, but must include the pertinent conditions existing in the surrounding civilian community. Consequently, the general sanitary survey of a station or command may, for the purpose of discussion, be divided into two general parts—first, that pertaining to the station or command proper and, second, consideration of conditions in civilian communities which would affect the health of the troops concerned. However, as a matter of fact, it may be difficult in many situations to separate the conditions existing in a post or camp from those found in adjacent civilian territory.

Sanitary survey of a military station or command. Usually, the factors to be considered in a sanitary survey of a military establishment can be placed in certain broad, general, but fairly well defined groups. However, these groups are not fixed and local conditions will, at times, require additions thereto or changes in the nature of the data to be obtained. The groups outlined below are suggested as a guide in the conduct of a sani-

tary survey, but do not constitute a form which can be adhered to in all instances.

A. **Military features.**

a. Military personnel.

Strength.

Training and discipline.

Racial characteristics.

b. Mission of the troops.

Peace time training.

Mobilization.

War time training.

c. Funds and policies.

Existing and prospective availability of funds.

Policies relative to the procurement and expenditure of funds.

B. **Environmental features.**

a. Topographical and meteorological conditions.

Nature of terrain.

Character of topsoil and subsoil.

Amount of rainfall; mean temperature and humidity; winds and seasonal variations in climate.

b. Recreational facilities.

Athletics.

Entertainment and welfare work.

c. Water supply.

Sources.

Methods of purification.

Methods of distribution.

d. Waste disposal.

Kinds of wastes.

Methods of disposal.

e. Housing.

Kinds of shelter used.

Ventilation, heating and lighting.

Bed spacing.

f. Food supplies.

Sources.

Effectiveness of inspection methods.

Storage and protection.

Operation of messes.

Training and supervision of food handlers.
Quality of the ration as served.
Operation of bakeries and post exchanges.

g. Insect control.
Kinds of disease-bearing insects present.
Control methods employed and their effectiveness.

h. Stables.
General cleanliness.
Fly control methods used and their effectiveness.

i. Recreation.
Facilities for recreation and their suitability.
Kinds of sports provided.
Swimming pools.
Theaters.

C. **Disease prevalence.**

a. Morbidity rates.
Average total sick rate.
Average admission rates for communicable diseases.

b. Communicable diseases.
Epidemic and endemic prevalence.
Sources of infection.
Control measures.

c. Hospital facilities.
Capacity of local hospital installations.
Facilities for segregation and isolation.

Sanitary survey of civilian communities. A sanitary survey of a civilian community, when made as a part of a general survey of a military establishment, is primarily concerned with those conditions which would be instrumental in the transmission of disease to troops. The factors usually considered in the conduct of such a survey are outlined below. Again, as in the survey of a military establishment, as outlined above, these groups are suggested as a guide, not as a form which can be followed in all instances.

A. **Towns or cities accessible to troops on pass.**

a. Social and economic status of population.
Principal occupations and industries.
Living conditions.

b. Health agencies, health laws and regulations.

Type of health department of municipal government.

Types of non-official health agencies, such as welfare organizations, clubs, etc.

Character and adequacy of health laws and regulations.

Enforcement of health laws and regulations.

c. Recreational facilities for troops.

Theaters, amusement parks, bathing beaches, etc.

Nature of supervision exercised at these places by health authorities.

d. Environmental factors.

Character of water supply.

Character of restaurants and other eating places and supervision by health authorities.

Crowding on street cars, in theaters, etc.

Prevalence and control of disease transmitting insects.

e. Prostitution.

Extent of prostitution.

Laws relating to prostitution and their enforcement.

f. Disease prevalence.

Epidemic, endemic or sporadic prevalence of communicable diseases.

Seasonal variations.

Sources of infection.

Control measures employed by local health agencies.

B. **Rural districts accessible to troops.**

a. Population.

Density.

Social and racial status.

Industries.

b. Water supplies.

Sources, such as wells, springs or streams.

Potability.

Supervision and control by state or county health authorities.

c. Roadside restaurants.

Cleanliness.

Supervision and control by county or state health authorities.

d. Insects.

Types of disease transmitting insects.

Control measures employed or required by civilian authorities.

e. Terrain.

Nature of terrain adjacent to military territory.

Mosquito breeding places.

f. Prevalence of disease.

Epidemic and endemic diseases prevailing among civilian inhabitants.

Sources of infection.

Conduct of a sanitary survey. The first step in the conduct of any sanitary survey is the formulation of a more or less complete plan relative to the kind of information that is to be obtained, the sources from which it is to be secured, and the methods which are to be employed in obtaining it. Such a plan will frequently obviate a needless dispersion of time and effort and will insure definite results. Depending on the extent of the survey, the plan may be written, wholly or in part, or it may be a well thought out line of action which is not necessarily reduced to writing.

The information sought in making a sanitary survey is obtained in a variety of ways. That pertaining to the strictly military features, such as personnel, funds and policies, can usually be secured from the command headquarters. In the case of the larger establishments, such as mobilization or training camps, data of this kind are normally obtained from or through the proper staff divisions, usually G-1 and G-4. Friendly relations and personal contact with the officers concerned are essential in the conduct of this part of the sanitary survey.

The environmental conditions within the post or camp must be determined chiefly by personal inspection and study of the installations and facilities concerned. The methods of making such inspections and studies have been considered in detail in previous chapters dealing with the various subjects concerned. Certain kinds of information are obtainable from

records, such as operating data for a water purification plant. Other data, such as that pertaining to orders issued and their enforcement, are secured by consultation and interview with the responsible officers.

Frequently, a major part of the information desired relative to sanitary conditions in civilian communities can be secured through contact with local governmental health agencies. Such contact should be personal and the surveying officer should not ordinarily endeavor to obtain information of this nature by correspondence or by questionnaires. In other instances, it will be necessary and desirable for the surveying officer to make personal observations or inspections of conditions existing in civilian territory.

The prevalence of epidemic and endemic diseases among the troops is determined by the analysis of past records and the epidemiological study of prevailing diseases. The prevalence of infectious diseases in the surrounding civilian communities is determined by study of the official reports and by interviews with civilian health officials. The morbidity reports of a civilian community, while not accurate as to actual number of cases, do indicate the epidemic, endemic or sporadic occurrence of disease. Civil mortality reports are usually accurate, but they do not show the incidence of the non-fatal or rarely fatal diseases, such as mumps or measles.

The officer making a sanitary survey must possess practical knowledge of the installations and conditions he inspects in order that he may be able to interpret his findings properly and arrive at sound and logical conclusions. Further, if the results of the survey are to have full value he must be able to make sound and practical recommendations for the correction of any defects and deficiencies that he finds.

Reports of sanitary surveys. The medical officer making a sanitary survey does not possess the authority to order the institution of corrective measures, except when such authority is delegated to him by the proper military headquarters. Normally, a report of a sanitary survey, including recommendations for the correction of defects and deficiencies, is forwarded by the surveying officer to the military headquarters of the establishment surveyed. There such action is taken as may be deemed practicable and desirable. Correc-

tive measures are instituted and accomplished in accordance with the orders of the military authority concerned.

Army regulations provide for routine monthly *sanitary reports* from all stations and tactical commands. Provision is also made for the rendition of special and informal sanitary reports as the need for such reports arises. The routine sanitary reports are based upon and are reports of either limited or general sanitary surveys made by or under the supervision of the surgeon of the command concerned. These reports are submitted by the surgeon to the commanding officer of the station or tactical command who takes such action as may be required or practicable for the correction of defects as recommended in the sanitary report. The reports are then forwarded to the Corps Area or Department Headquarters and then to the War Department.

General sanitary reports may be made of sanitary surveys conducted by medical inspectors appointed by the Surgeon General, the chief surgeon of a theater of operations, or higher authority, by Corps Area or Department medical inspectors, or by medical inspectors of communications zone sections, corps and armies.

The form and content of the routine sanitary reports and the channels through which they are to be transmitted are prescribed in Army Regulations 40-275, November 15, 1932.

Monthly sanitary report. The monthly sanitary report is rendered by the surgeon of each station or tactical command in the field within three days after the end of each month. The purpose of the monthly sanitary report is to keep commanding officers and higher administrative authorities in touch with current sanitary and health conditions within the station or command concerned.

December sanitary report. In addition to the data required for the monthly report, the December report contains a brief resume of sanitary conditions during the *year* and a discussion of all factors which have affected the health of the command. A summary of important sanitary defects and deficiencies reported during the year with the corrective action thereon is included.

Special sanitary reports. The special sanitary report is designed to cover emergencies which arise in the interim between monthly reports. The purpose of the special sanitary report is to place immediately before commanding officers information

and recommendations regarding grave sanitary defects, epidemics, or other conditions that are seriously affecting or may immediately affect the health of the command.

SANITARY SURVEY OF TEMPORARY CAMP OR BIVOUAC SITES

The selection of temporary camp or bivouac sites is governed by a number of factors which may be classified as "military" and "sanitary". The importance of the military factors, as compared with the sanitary factors, depends on the military situation. In the presence of the enemy, or in the prosecution of a plan upon which the success of military operations depends, the military factors are of first importance and sanitary considerations are relegated to a secondary place. However, when the military situation permits, the health of the troops is of primary importance and the sanitary aspects of camp or bivouac sites are then given first consideration.

Ordinarily, a definite site for a camp or bivouac is selected for a company, battalion or regiment because these organizations are the basic units of a military force. Field orders may give the camp or bivouac area for a brigade or division, but the area is, as a rule, designated in general terms only and the responsibility and authority for the selection of actual sites within the designated area are delegated to subordinate commanders.

Military factors. The mission of a military force, whether it is training or combat, is the primary military factor to be considered and all other activities must necessarily be subordinate thereto. When troops are moving into combat, but little, if any, consideration can be given to the sanitary features of a proposed bivouac site, and the selection of sites will be governed entirely by the military situation.

When troops are moving into a concentration area, greater latitude may be permitted in the selection of camp or bivouac sites. Under these circumstances, the degree of consideration which can be given to sanitary factors will be determined by, first, the nature and purpose of the concentration, such as concentration prior to immediate combat, concentration for training, or for rest purposes preparatory to or subsequent to combat and, second, the nature of enemy activi-

ties, such as observation or attack from the air or danger of raids or surprise attacks by ground troops.

In the movement of troops through friendly territory, or through occupied territory not in the presence of the enemy, the selection of camp or bivouac sites may become largely a sanitary matter.

Road net and means by which troops are moved. The nature of the road net, the condition of the roads and the means by which the troops are moved (on foot, mounted, or by trucks) serve to restrict and limit the sites which can be selected for camps or bivouac. The distance which foot troops can be moved during a day's march is limited to a normal maximum of about 20 miles. Thus, an otherwise desirable site may be eliminated by the fact that it cannot be reached by the troops without undue physical exertion. Motorized units may, however, lengthen the day's march by a number of miles in order to reach a satisfactory camp or bivouac site. Because of their greater mobility, mounted units may also be able to utilize areas which could not be reached by foot troops.

Motorized units are, however, restricted to fairly good highways, while foot or mounted troops can travel over poor or unimproved roads. Thus, within their respective marching distances, foot or mounted troops have more opportunities for a wider selection of camp or bivouac sites than motorized troops.

Supply. A site for a camp or bivouac may be rendered undesirable for a subordinate unit of a larger command because it is located at too great a distance from distributing points for rations or other supplies. In other instances, the condition of the roads leading to a satisfactory site may be such that, while they can be used by foot or mounted troops, they will not permit the passage of vehicles carrying supplies.

Sanitary factors. *Terrain.* The character of the soil may be a factor of considerable importance. During rainy seasons, the surface slope and the character of the subsoil and the uppermost impervious stratum should be considered in connection with drainage. Sites which have a top soil of loam, or loam and sand, or an underlying stratum of till, limestone, or sandstone, are usually well drained. Clay, either as top soil or as an underlying stratum, usually interferes with drainage.

If sanitary appliances, or other camp appurtenances, which will require excavations are to be installed, the depth of any

rock or clay stratum and of the ground water table below the surface of the ground should be considered.

The topography, shape and size of the site in question should permit of an orderly arrangement of the tents by companies or, if practicable and necessary, by larger units. Steep grades render it difficult to prevent flooding of the tents in the event of rain. Troops can not rest properly when they are compelled to sleep on steeply inclined, uneven or stony ground. It is not desirable to have a part of an organization separated from its kitchen, drinking water supplies, or latrines by marshes, ravines, streams or long distances. On the other hand, undue crowding of tents and unit installations should be avoided.

A camp or bivouac site should be comfortable for the troops. In hot climates, or during the summer season in temperate climates, moderate amounts of shade and grass are desirable. Sandy soil and excessive dust usually render a camp uncomfortable and while they are not factors in the transmission of disease, they do impair morale and are to this extent of sanitary significance.

Water supply. If local water supplies are to be used and the water purified in water sterilizing bags, a sufficient supply must be obtainable from sources not beyond the reach of, or inaccessible to, water carts, either animal or motor drawn. If the water is to be supplied by means of a mobile water purification unit, the source may be at a distance from camp provided the character of the road net, condition of roads and the nature of the military situation will permit transportation of water in truck tanks, water carts, or otherwise (page 354).

The quantity of water obtainable from a surface supply may be limited by accessibility, and consideration must be given to the nature of the banks and the points at which the water can be reached by water carts or water purification units. It is always difficult and may be impossible to determine the quantity and accessibility of a water supply from a map and, usually, a water reconnaissance must be made (page 370).

Occasionally, ground water obtained from wells or springs may be utilized. In selecting a camp site where well water alone is available, care must be taken to ascertain that the supply will be sufficient for the needs of the troops (page 363). Frequently, wells which furnish sufficient water for farms or fam-

ilies become quickly exhausted when drawn upon to supply troops.

At times, though rarely, springs may serve as a source of water supply. In these cases, the principal features of sanitary significance are the quantity, and the methods by which the spring can be protected from excessive pollution with mud and debris while being used by the troops.

Contact between the troops and civilian inhabitants. Sometimes, though perhaps infrequently, the density and character of the population of the territory adjacent to a proposed site becomes a determining factor in the selection of a camp site. Cities, towns and villages, with their theaters, amusement parks, and other places where crowds congregate, may become important factors in increasing the exposure of troops to respiratory diseases. They may also provide ready access by the troops to contaminated food and water supplies. Further, in war time it is difficult to prevent increased exposure to venereal diseases when troops are camped near centers of population.

If practicable, the site for a camp or bivouac should be located at a reasonable distance from any center of population. However, the advantages of having a camp close to small centers of population for supply and other purposes will frequently outweigh the disadvantages arising from contact between the troops and the civilian population.

Mosquito breeding places. Mosquitoes may be either a source of annoyance to troops or carriers of disease. Camp or bivouac sites in the vicinity of mosquito breeding places should be avoided, and this is especially true if the mosquitoes are species which carry malaria or dengue, and if either of these diseases is prevalent among the inhabitants of the locality in question.

Fly breeding places. The fly breeding propensities of garbage dumps or stables may constitute a distinct menace and troops should not be camped in the neighborhood of such places, unless such action is rendered necessary by other circumstances.

Methods of selecting camp or bivouac sites. The decision as to the actual site to be selected is made by the commanding officer of the organization concerned, or by a subordinate officer to whom the commanding officer delegates the authority to make such decisions. Ordinarily, the available sites or areas are investigated and determined upon by quartering or reconnoitering parties, of which a Medical Department officer act-

ing as a staff officer is a member. The Medical Department officer participates in the selection of the site by making necessary and pertinent recommendations relative to sanitary features.

Area required for bivouacs. The size of the area which may be utilized for a bivouac for a unit varies considerably, depending on the nature of the terrain and the mission of the unit. The following table shows the areas normally required for the units of a division:

APPROXIMATE AREAS REQUIRED FOR BIVOUACS FOR A DIVISION

	Dimensions Yards		Area in Acres
	Depth	Breadth	
Division headquarters and special troops	110	275	6.3
Infantry brigade headquarters and headquarters company	170	20	.7
Infantry regiment	170	285	10.0
Infantry brigade	170	600	21.0
Headquarters and headquarters battery, field artillery brigade	213	50	2.2
Field artillery regiment (75-mm gun)	260	990	53.2
Field artillery regiment (155-mm how.)	260	880	47.3
Field artillery brigade ammunition train	240	230	11.4
Field artillery brigade	——	——	167.2
Combat regiment, Corps of Engineers	170	100	3.5
Medical regiment	170	240	8.5
Quartermaster regiment, infantry division	140	340	9.8
Total for a division	——	——	237.3
Cavalry regiment	190	255	10.0

SANITARY ORDERS

A sanitary order is administrative in character and provides for the execution of sanitary procedures applicable to and indicated in the prevailing situation and designates those responsible for the enforcement of such measures. It is in effect a sanitary code for the command concerned and corresponds to the sanitary code of a civilian community.

The commanding officer is responsible for the issuance of a sanitary order. While the surgeon of a command acts in an advisory capacity in the formulation and preparation of a sanitary order, it is published by the order, or over the signature of the commanding officer.

Scope and contents of a sanitary order. The sanitary order contains all the administrative details necessary to protect the health of the troops and applies with equal force to all elements of the command. As in other military orders, the sanitary order normally states what will be done and, if indicated, when certain activities will be performed, but does not give the detailed methods to be employed in accomplishing the measures directed. While, because of its nature, the sanitary order cannot be written strictly in accordance with the methods employed in writing a combat order, the principles to be observed are the same, in that the higher commander does not encroach upon the responsibilities or hamper the initiative of his subordinate commanders by issuing detailed orders as to how the desired results are to be obtained. Consequently, the sanitary orders issued by the commander of a larger organization, such as a division, are general in character and provide a basis for more detailed orders to be issued by subordinate commanders.

Preparation of a sanitary order. The surgeon of a command is normally responsible for the preparation of a sanitary order. He may, in practice, delegate the actual writing of a sanitary order to his medical inspector, but in so doing he does not delegate his responsibility for its proper preparation.

In the preparation of a sanitary order, the surgeon must be conversant with the health situation within the command and with all factors which affect or might affect the health of the troops. He must give full consideration to the mission of the command and to the facilities which are available for the accomplishment of sanitary measures. All measures directed by a sanitary order must be of a practical nature. They should be necessary to meet the sanitary needs of the command, compatible with the mission of the command, and of such character that they can be accomplished with the facilities available.

The sanitary order as prepared by the surgeon is submitted to the proper military headquarters for approval and publication to the command. In the ordinary small post or camp,

the proposed order is submitted to the commanding officer for approval and issue. In the larger stations or camps or in larger tactical commands, the order is usually submitted to G-1 of the staff who coordinates it with other staff sections and then submits it in turn to the chief of staff for approval and issue.

Form of sanitary orders. A sanitary order may be issued in the form of a general order, as an annex to an administrative order, or as a series of memoranda or instructions.

A complete sanitary order can remain effective in all its provisions and meet all requirements only for a comparatively short period of time. Changes in the environmental conditions or modifications in the military mission will necessitate more or less frequent revision of an existing sanitary order, or the publication of new orders. Consequently, in the case of permanent or semi-permanent establishments and in the higher echelons of a field force, orders relative to sanitation are issued from time to time in the form of memoranda or instructions for the correction of sanitary defects as they occur. Normally, general headquarters, or army, corps, or communications zone headquarters do not publish sanitary orders as such, but govern sanitation from an administrative point of view by the promulgation of policies pertaining thereto or by instructing subordinate commands relative to action to be taken by them to meet a particular sanitary situation.

When a sanitary order is issued as a general order or as an annex to an administrative order, it is usually complete and contains all the instructions for the administrative control of sanitation in the situation to which it pertains. These forms are utilized when the time during which the order will be effective will not be sufficiently long to permit changes in health conditions because of variations in environment or in military activities. In situations where an administrative order is not applicable, the general order form is ordinarily employed for independent regiments or brigades, divisions, units of corps or army troops and GHQ reserves, troops and installations of the communications zone, and similar organizations. During peace or in the zone of the interior in war, a sanitary order may be issued in the form of a general order for a tactical unit or for camps, where the existing situation is of a more or less temporary nature. For example, a sanitary order would nor-

mally be published as a general order for a division or an analogous command in a mobilization or concentration camp, or for a summer training camp. The sanitation of temporary installations would also be controlled by a sanitary order in the form of a general order.

The form in which the details of a sanitary order are published will vary with the conditions under which the order must be enforced. It is customary, however, to employ certain general paragraph headings which are applicable to a greater or less extent in most situations. The following outline of a sanitary order shows the general paragraph headings which in turn indicate the nature of the contents of the order. This order may be issued for a division or a similar body of troops in camp or rest area, subject to modification for larger or smaller units, for varying environmental conditions, and in accordance with the time it is to remain in force.

.... Division
.... (Place)
.... (Date)

General Order)
No.)

1. *General.* The following provisions for the sanitation of this division are published for the information and guidance of all concerned:
   a. Responsibility of unit commander.
   b. The division surgeon (duties and responsibilities relative to sanitation).
   c. The medical inspector (duties and responsibilities).
   d. Water supply.
   e. Food and messes.
   f. Waste disposal.
   g. Quarters (barracks, tents or billets).
   h. Insect control (where applicable).
   i. Personal hygiene.
   j. Dispensaries (location).
   k. Venereal prophylaxis (location of stations).

l. Physical inspections.
m. Special measures for the control of communicable diseases.

2. *Civilians.* All civilians and civilian organizations attached to the division will comply with this order in so far as it applies to them.

By order of ....

....

Official:
Distribution.

While army regulations fix the responsibilities of all concerned with regard to sanitation, the sanitary order, as a rule, again states the responsibility of the unit commanders, the surgeon, and the medical inspector. This is done in order that the duties of each, and the relations of one to the other in the existing situation may be clearly defined. Under some circumstances it may be desirable to state in the sanitary order the responsibilities of other staff officers such as the quartermaster, the engineer officer, or the police officer.

CHAPTER XXVII.

PHYSICAL EXAMINATIONS

Only the principal administrative features of physical examinations are considered in this chapter. These include the purpose, scope and character of physical examinations as performed in the army, the organization of examining boards and methods of conducting examinations.

Physical examinations constitute an important part of military preventive medicine and are essential in protecting the health of military personnel. Further, troops cannot be recruited or mobilized for military service without being physically examined and the performance of physical examinations is the first step in the recruitment or mobilization of a military force. Usually, it is the principal basis upon which men are selected for enlistment in the military service. The efficient performance of large numbers of physical examinations, from both an administrative and a professional viewpoint, is a vital feature of mobilization for war.

The administrative responsibility for and control of physical examinations rest with the commander of the command or station concerned. The Medical Department is responsible for the performance of physical examinations in accordance with administrative orders of competent military authority.

All persons entering the military service are physically examined and certain classes of military personnel are given periodic examinations while in the service. The physical examinations which are made at the time of entry into the service or when the individual comes under military control are performed primarily to exclude those who are unable to perform military duties or who would, because they are physically defective, impair the military efficiency of the unit to which

they belong. These examinations also serve to protect the interests of the Government by excluding those who would tend to require excessive hospitalization while in the service or who would shortly become eligible for compensation or pension because of physical disability.

The principal purpose of periodic physical examinations or physical inspections is to conserve health by the detection, with subsequent correction, of physical defects and abnormalities. The physical examinations for entrance into the service are also, to a certain extent, health conserving measures, in that they afford an opportunity to detect abnormalities which do not disqualify the examinee for the military service but can, nevertheless, be corrected with consequent improvement in health.

STANDARDS OF PHYSICAL QUALIFICATIONS

Where physical examinations are made for administrative purposes, as, for example, to determine if the examinee is physically fit for admission to the military service, for promotion, for active duty, etc. (*infra*), minimum standards are necessary in order to insure efficiency in the conduct of the examination and to secure uniformity of results and of administrative action. Standards of physical qualifications are formulated and promulgated by the War Department and are published in army regulations.

A physical defect or condition may be decreed by army regulations to be disqualifying solely because it would interfere with the performance of certain military duties and not because it would impair the health of the individual under military conditions. For example, height of less than 64 inches, or the loss of more than one phalanx from the right index finger, are physical conditions which, under the present policies of the War Department, are considered to be disqualifying for military service. Such conditions do not, of course, affect health or interfere with the pursuit of many civilian occupations.

Where a regulation prescribes that a condition or defect is disqualifying, an examiner or examining board cannot waive the regulation and accept the examinee for service. A waiver can be granted only by the authority promulgating the regulations, which is the War Department. Certain physical defects are,

however, disqualifying for military service only when developed to more than a given degree or extent. Thus, overweight or underweight, flat feet, or defective vision are some of the defects which may or may not be disqualifying. Whether they are disqualifying must be determined by the examiner. If a defect of this character is disqualifying according to the existing standards, but is not disqualifying in the opinion of the examiner, the examining board cannot accept the examinee, but should recommend to proper authority that a waiver be granted.

SCOPE AND PURPOSE OF PHYSICAL EXAMINATIONS

The physical examinations performed in the military service are:-

a. For enlistment or for selection under a selective service law (draft).

b. For commission in the Regular Army.

c. For admission to the United States Military Academy.

d. For promotion of officers in the Regular Army.

e. For retirement of officers for physical disability.

f. Prior to resignation or discharge.

g. For flying duty.

h. For commission in the Reserve Corps.

i. For promotion in the Reserve Corps.

j. For active duty under a Reserve Corps appointment.

k. For admission to Reserve Officers' Training Corps Camps and Citizens' Military Training Camps.

m. Annual physical examination of officers and warrant officers.

n. Miscellaneous and special examinations, such as the examination of deserters, or of enlisted men prior to transfer to tropical service, etc.

The physical examinations of National Guard personnel are in general the same as those of the personnel of the Regular Army and Organized Reserves.

Examination for enlistment. The purpose of the physical examination for enlistment is to determine if the examinee is physically capable of performing military duties during the enlistment period, which is usually three years. The standards are not as high, nor are they as strictly interpreted as those for commission or for admission to the Military Acad-

emy. The detection of abnormalities which would actually or potentially be the cause of hospitalization or result in discharge from the service prior to the expiration of enlistment is of paramount importance in the performance of this examination.

At times the desire to obtain or the need for recruits may tend to influence medical examiners to accept men who are potentially physically unfit for military service. It should be remembered that the Government has little to gain and much to lose by accepting for enlistment a man who is actually or potentially physically incapable of performing military duties.

Examination for commission in the regular army. When an individual is commissioned in the regular army it is contemplated that he will serve for a long period of years. The physical examination of an applicant for a commission should therefore be thorough and complete. Particular attention should be devoted to the detection of obscure or incipient abnormalities which might later develop into conditions that would impair the efficiency of the individual or incapacitate him. Where the significance of apparently slight abnormalities cannot be immediately determined, arrangements should be made to observe the examinee, in hospital or otherwise, for a period of time which will permit a definite diagnosis to be made. This procedure may, for example, be adopted where the examinee has an albuminuria which may be transient, or a cardiac condition that cannot be diagnosed without further study, such as cardiac murmurs which may or may not be organic in origin. The examinee should of course be rejected where there is finally any doubt as to his meeting the physical requirements for a commission.

Examination for admission to the Military Academy. The applicants for admission to the Military Academy are, as a group, youths who are not as yet physically mature. The Government invests a considerable sum in the education of each cadet with the expectation that he will be mentally and physically qualified for a commission on graduation. It follows, therefore, that in order properly to protect the interests of the Government, the physical examination for admission to the academy should be particularly thorough and complete. Physical standards should be strictly adhered to and the physical requirements for acceptance maintained at a high

level. In general, no examinee should be accepted who possesses any physical defect that might develop into an abnormality which would prevent him from being commissioned on graduation or result in early disability or retirement after being commissioned. The political and other interests involved in the admission of candidates to the Military Academy render a strict interpretation of the standards of physical qualifications especially important.

Examination for promotion of officers of the regular army. The general purpose of the physical examination for promotion of officers of the regular army is to determine if the examinee is physically qualified to perform all duties of the rank to which he is eligible for promotion. Naturally, the requirements are not as high as for original commission, and examiners must exercise judgment in the application of the physical standards to determine if a given condition disqualifies for promotion.

This examination also differs from the examination of applicants for entry into the service or for admission to the Military Academy in that it is of distinct value in the conservation of health. The examinees are under military control and proper measures can be taken to correct defects found by the examination. The examination for promotion is in this respect similar to the annual physical examination (*infra*). It may replace the annual physical examination for the year in which it is made.

Examination for retirement for physical disability. An officer of the regular army is retired from active service when because of permanent physical disability he is incapacitated for active service. Ability to perform active service is generally interpreted as ability to perform the duties of his rank and arm or service to which he belongs. A formal physical examination must be made as a part of the retirement proceedings and the action of the retirement board is based on the results of this examination and is final. As a rule, the examination is made by two medical examiners who appear as witnesses before the retirement board. The examination should be complete, regardless of the nature of the disability. The medical examiners must determine whether the disability is of such nature as to incapacitate the examinee permanently for active service and if it was contracted in line of duty.

Examination for flying duty. The physical requirements for flying are such that a special physical examination must be made to determine if the examinee is physically qualified for such duty. Special standards of physical qualifications are employed and owing to the highly technical nature of this examination, it should be made only by examiners who have had special instruction and training. At the present time the physical examination of military personnel for flying duty is conducted only by medical officers who have been authorized to do so by the Surgeon General of the Army.

While the primary purpose of the physical examination for flying duty is to determine if the examinee possesses the physical qualifications which will enable him to learn to fly or to continue flying, it is also of value in conserving health. Remedial measures are taken to correct abnormalities and defects which are revealed by the examination, even though they do not incapacitate for flying duty. The physical examination for flying may replace the annual physical examination (*infra*).

Examination prior to resignation or discharge from the service. An officer who resigns from the regular army is physically examined shortly before his resignation becomes effective and enlisted men are examined prior to discharge from the service. The purpose of this examination is to obtain an official record of the physical condition of the examinee at the time of separation from the service for the protection of the interests of both the Government and the individual, should claims for compensation or hospitalization be made at some future time. Special attention should be given to the detection of actual or potential disabilities incurred in the service and any abnormality the adverse effect of which may have been accentuated by military service.

Physical examination of reserve officers. The reserve officer must be examined as a candidate for commission, for promotion, and at the beginning of any period of active duty. During peace a reserve officer cannot under existing laws be retired because of disability incurred in line of duty. In most instances, active duty periods are short and are devoted to training, usually in training camps. In view of these conditions, the physical requirements for commission or promotion in the reserves and for active duty during peace are not as

high as those for regular army officers. The primary purpose of the physical examination for a commission or promotion is to determine if the examinee is potentially physically qualified for duty during a future war. The physical examination for active duty during peace is intended to determine if the examinee is physically fit to perform the training duties required at the time.

Physical examination of student trainees. Members of the Reserve Officers' Training Corps and of Citizens' Military Training Camps are not members of the army but they are under military control while in training camps. Consequently, they are physically examined before being accepted as students in a training camp. The purpose of this examination is, first, to insure that the accepted applicants are physically able to undergo training and, second, to protect the Government against unwarranted claims for hospitalization.

The examination of Reserve Officers' Training Corps students is also made with a view to determining if the examinee will be physically qualified for a commission in the reserve corps after completion of training. In most instances, a relatively large number of examinations must be made in a short period of time, but, nevertheless, the examinations should be thorough and complete. If physically defective applicants are accepted, they will hamper the training of others and tend to cause the Government unnecessary expense for treatment and care. Also, there is always danger that a trainee who is physically unfit will suffer further impairment of health as a result of training.

Applicants for admission to a Reserve Officers' Training Corps unit are usually examined at the schools where the unit is formed. This examination has for its principal purpose the elimination of those applicants who possess physical defects which would prevent them from being commissioned in the reserve corps on completion of the training. It may be performed by medical officers of the army or by civilian physicians.

The annual physical examination of officers. All officers of the regular army, including warrant officers, are physically examined once each year. This annual examination is performed solely for the purpose of protecting and promoting health and largely for the benefit of the examinee. It also

serves to protect the interests of the Government in that it is an important factor in maintaining the physical fitness of the officer personnel.

In the conduct of the annual physical examination, special attention should be given to the detection of habits or defects in the mode of living which would have an adverse effect on health. A special effort should also be made to determine the presence of minor abnormalities and conditions which only potentially affect health in order that, by their early correction, the development of more serious conditions may be prevented.

The success of the annual physical examination in promoting health depends, to a very considerable extent, upon the cooperation of the examinee. The desired cooperation can, as a rule, be readily obtained if the examinees are fully advised of the nature and purpose of the examination. This information can be transmitted to the examinees by any one of several methods. Circulars or memoranda may be issued by the proper military headquarters, or the subject may be discussed at an officers' call. In other instances, the president of the examining board may give the necessary information during the course of the examination. As a matter of fact, most of the officers of the permanent establishment are conversant with the character of, and with the results obtained by the annual physical examination, and are willing to give full cooperation.

The medical history is a very important part of the annual physical examination. It should be recorded on the report form (*infra*) before any other part of the examination is made in order that it will be available to other examiners throughout the course of the examination. It is essential that the medical history be complete, not only with regard to illness and injury, but also relative to habits which might affect health or physical fitness. Where pertinent, information relative to living and environmental conditions should also be obtained.

The medical history is usually obtained directly from the examinee at the time of the examination. It may, however, be practicable in some instances to send questionnaire blanks to examinees to be filled out with the history data prior to the examination and returned to the examining board at the beginning of the examination.

The examinee should be informed in writing relative to the correctible defects found during an annual examination. Where pertinent he should also be advised in writing as to the measures which he should take to correct the defects found. Further, the president of the board, or some member of the board, should discuss the results of the examination with the examinee and give him such advice as may be required. Where desirable, the board should recommend to the proper military authority such administrative action as may be necessary to correct or remove defects. This may include treatment, hospitalization, further observation, supplementary examinations, etc.

The reports of the annual physical examinations of each officer are eventually filed in the War Department where they constitute a continuous health record. Therefore, each examination should, for administrative reasons alone, be complete in every detail.

CONDUCT OF PHYSICAL EXAMINATIONS

The physical examination, whether performed for administrative or health conservation purposes, or both, is an examination of an apparently healthy person. It is seldom that the examinee complains of any symptoms or conditions indicative of a physical defect or abnormality. The methods used, therefore, differ to some extent from those employed in determining the cause or nature of an existing illness. The examinee may endeavor to conceal physical defects or he may malinger or endeavor to accentuate the importance of minor abnormalities. Consequently the examiner must be prepared to determine the true physical condition of the examinee and detect and properly evaluate any and all obscure or pre-clinical abnormalities.

Physical examinations must be thorough if they are to be of any considerable value either for health conservation or for administration purposes. Usually, if there are a number of examinees, administrative conditions require that the examinations be made as rapidly as may be consistent with thoroughness, but thoroughness should not be sacrificed to obtain speed. Where physical examinations are performed with such rapidity that the work is slighted, the results are of but little actual value and the object of the examination is defeated. Such examinations are in reality physical inspections only and should be so regarded.

If they are accepted as having the same value as properly performed physical examinations, they will tend to cause more harm than good, in that a great many examinees who actually have physical defects will be erroneously considered as physically fit for military service or will be denied the attention necessary to protect their health.

Examining boards. A physical examination may, of course, be made by one medical officer, but where any considerable number of examinations are to be made, an examining board of two or more members is usually appointed. An examining board should not ordinarily include more than twelve to fifteen examiners, as boards comprised of a greater number tend to be unwieldy and difficult to administer. Moreover, the number of examinations which can be performed by a board is not increased proportionately by an increase in the number of examiners. Where a large number of examiners are to be employed, better results will usually be attained if two or more boards are organized. The senior member of an examining board is the president of the board. The president supervises, directs and is responsible for the work of the board.

Examining stations. Each examinee may be completely examined by one member of the board, but where there is more than one examiner, the examination can be more thoroughly and more rapidly conducted if each examiner performs only a selected part. When this method is used the work to be done is divided into sections, each of which consists of related portions of the examination. The number of sections into which the examination may be divided depends, within limits, on the number of examiners and the character of the facilities available. An examining station is established for each section and the examinee is passed from one station to another during the course of the examination.

Organization of examining boards. Where only a relatively small number of persons are to be examined, a board of three members forms a very satisfactory working unit. Such a board requires but little organization, and the work can be more or less easily divided among the members. Larger boards must be much more highly organized if the examinations are to be performed without confusion and undue delay. Here the organization is based on the formation of examining stations, at each of which

one or more of the component parts of the examination are performed. The number of examiners assigned to each station will depend on the type of organization adopted and the work to be performed at each station.

The organization of an examining board should be such that the work performed at each station is thorough and complete, and a constant, steady flow of examinees is maintained through the various examining stations without congestion or undue delay at any one station. Figures No. 316 and 317 illustrate, diagrammatically, typical methods of organizing a board of twelve members. Nine examining stations are installed which employ eleven

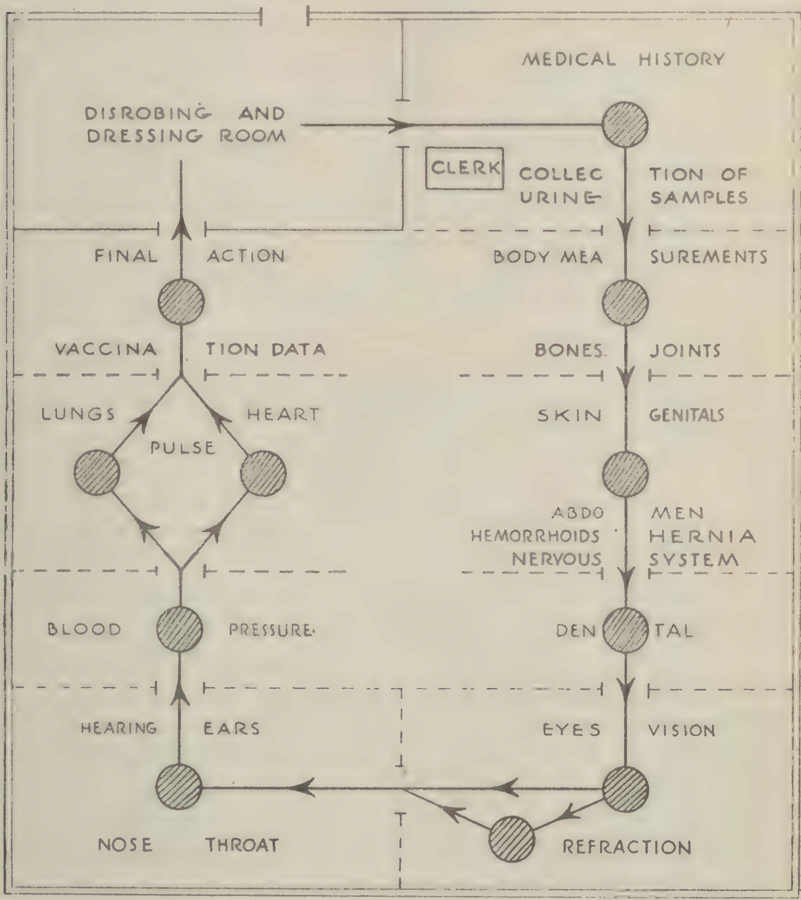


FIG. No. 316. Diagrammatic representation of the organization of a physical examining board. Nine stations and eleven examiners.

examiners. The president of the board is free to supervise and direct the work of the board. Two examiners are assigned for the examination of the lungs and heart, and two for the examination of the vision. A board of twelve examiners, when organized in this manner can examine from fifteen to twenty-five men per hour, not including those reserved for further examination or observation because of the presence of abnormalities.

Fig. No. 318 shows by a diagram one method of organizing a board of six examiners. One examiner is placed at each of five stations and the president of the board supervises the work of the entire board and assists at any station that may become crowded.

In some instances it may be found desirable to have one or even two or more examiners, who are not assigned to any particular station, to assist where their services may be needed to relieve congestion and to keep the line of examinees moving. Congestion and delay are most apt to occur at the stations where the chest and vision are examined, and, as a rule, in the operation of a well organized board, the rate at which the examinees pass through the station or stations for the examination of the heart, lungs and vision will determine the examination rate of the board as a whole.

Regardless of the manner in which an examining board may be organized, it will, in the great majority of instances, require readjustment during the first few hours or days of the examination. Medical examiners vary greatly in ability to perform physical examinations and it is usually necessary to make some changes in the amount of work to be performed at certain of the stations, or to reassign some of the examiners. Eventually, however, if the basic organization of the board is sound, a smooth functioning unit can be obtained.

The physical examinations for admission to the Military Academy and for commission in the Regular Army include Wassermann and Kahn tests for syphilis, and in the conduct of these examinations provision must be made for collecting the blood specimens and for forwarding the sera to the laboratory. Usually, it is most convenient to draw the blood at the beginning of the examination before the examinees disrobe, or when the urine samples are collected. In some instances, blood samples may be collected after the completion of the other parts of the examination. Occasionally, it may be desirable to draw the blood at a

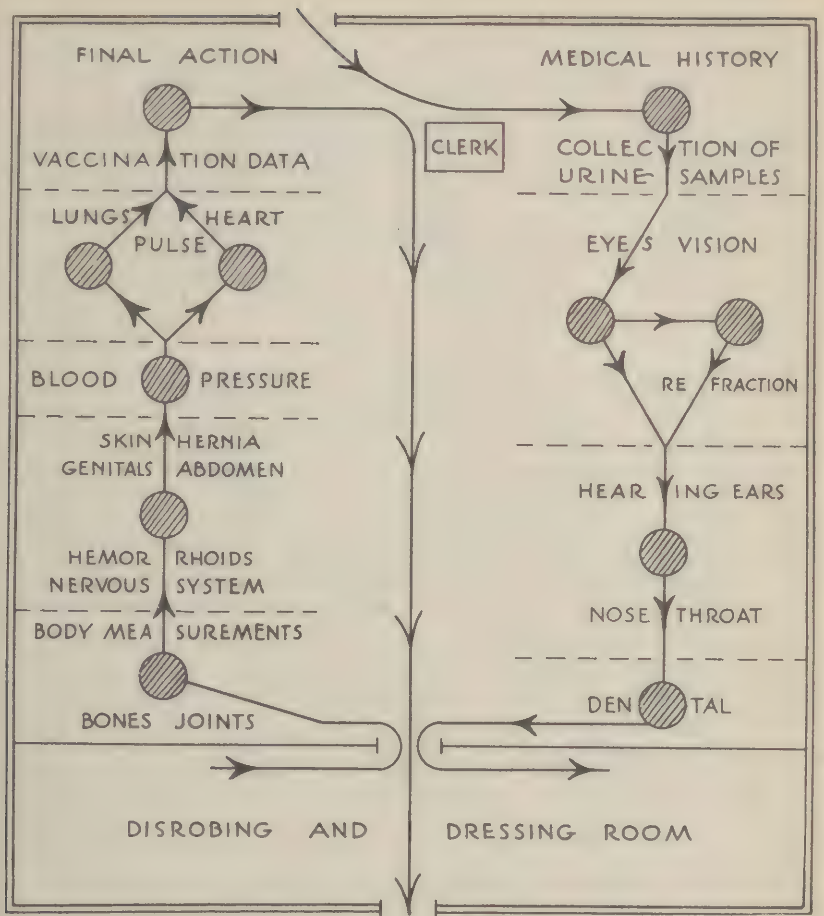


FIG. No. 317. One method of organizing a physical examining board which will permit partial examination before the examinees disrobe.

time when any shock that may be caused by bleeding will not interfere with the mental examination.

Where examinees are found to have abnormalities which cannot be definitely diagnosed at once, or are difficult to diagnose, they should be detained for further and more careful examination. The special examinations may be made by members of the board not assigned to a particular station or by specialists attached or assigned to the board for that purpose. Where large numbers of men are to be examined, a special or subsidiary

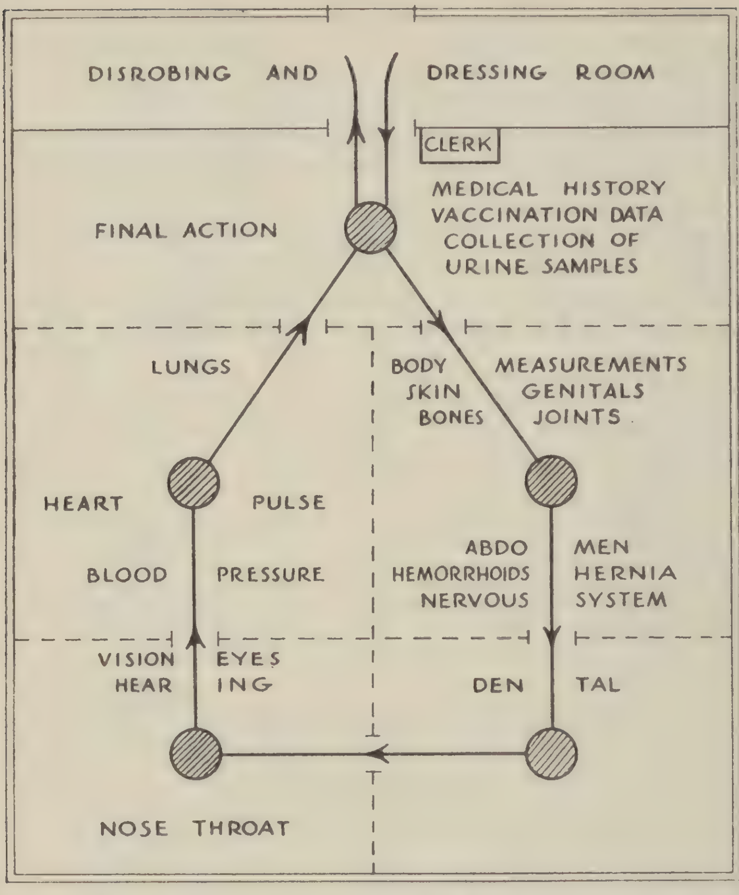


FIG. No. 318. Diagrammatic representation of the organization of a physical examining board. Five stations and six examiners.

board should be organized in addition to the principal board. Any examinee who presents evidence of a physical defect which is actually or potentially disqualifying is sent to the special board for further examination. In practice, the principal board sorts out and passes all examinees who are obviously physically qualified under the existing standards. The special board reexamines all doubtful cases and makes all rejections. This method has the advantages that the principal board can work at a higher speed without depreciation in the thoroughness of the examination and the special board can devote all the time necessary to the ex-

amination of the doubtful cases. Where practicable, the special board should include or be composed of specialists.

Physical examinations can be performed with the least discomfort to the examinees if the clothing is removed for only as short a time as practicable. However, where disrobing occurs at some point during the course of the examination, control over the line of examinees is temporarily lost and the continuity of the examination is broken, with consequent confusion and delay. Under ordinary conditions it will generally be found more satisfactory to have the examinees nude throughout the entire examination.

Where boards are organized as shown in Fig. No. 316 or Fig. No. 318, the examinees disrobe before undergoing any part of the examination and remain nude throughout the entire examination. Fig. No. 317 shows a method of organizing a board so that the medical history can be taken and the examination of the eyes, ears, nose, throat and teeth can be made prior to disrobing. The examinee is entirely or partially nude for the remainder of the examination.

The methods of organizing a board as discussed above are examples only and are subject to many variations. The organization adopted will depend largely on the number of examinees, the number of examiners and the kind of facilities available. The amount and character of the floor space and the size, number and arrangement of the rooms to be used for the examination will also influence the organization of the board.

FACILITIES

Sufficient space should be available to permit the examiners at one station to work without interfering with the work at another station. Ideally, a separate room should be provided for each station. Where this is not practicable, and it usually is not, several stations may be grouped in one room. In some instances, it may be found expedient and feasible to separate stations by means of screens or partitions. In any event, the physical arrangement and grouping of the various examining stations should be such as to reduce noise and confusion to a minimum. Particular care should, for obvious reasons, be taken to eliminate noise from the vicinity of the stations for the examination of the chest, blood pressure and hearing.

Examining rooms should be well lighted. It is especially important that the station where the vision is examined be provided with adequate light. If the natural lighting available is insufficient, artificial lighting should be provided.

If the examination is held during the colder seasons of the year, care must be taken that the temperature in the room or rooms is comfortable for nude examinees, that is from 72°F. to 74°F. If found practicable, bathrobes and slippers may be furnished examinees. Rain coats may be used in lieu of bathrobes.

Examining rooms should be well ventilated. Good ventilation is especially important during the summer months, or if a large number of men are to be examined.

It may be found desirable to install a bed or cot for use in making special examinations requiring a recumbent position and for examinees who become ill.

Each examiner should be provided with one or more clerks, usually enlisted men, to take down on the report form the examination data as dictated by the examiner.

REPORT FORMS

The results of physical examinations are entered on printed report forms which serve as a means of recording the data obtained and to some extent as guides for the conduct of the examinations. The report form is not, however, a measure of the extent of the investigation into the health of the individual and should not be so regarded.

The various official report forms used for recording the results of physical examinations are prescribed by the War Department. At the present time the form known as W.D., A.G.O. No. 63 is used to record and report the results of all physical examinations, except for enlistment, for flying and for admission to the Military Academy or to Citizens' Military Training Camps. While report forms may vary as to the arrangement of the headings and spaces, and are in this respect subject to change from time to time, they all contain the essential data obtained by a physical examination.

That part of the report form showing the name, rank, grade, age, etc., of the examinee should be filled out at the beginning of the examination. This is usually done by an enlisted clerk.

PHYSICAL INSPECTIONS

Army regulations require that all enlisted men be physically inspected once each month. The men to be inspected should be nude. Special attention should be given to the detection of signs or symptoms of physical deterioration, such as anemia, underweight, poor posture, etc. Evidence of infectious disease, including venereal disease, should be sought. The teeth and the feet should be carefully examined. The general cleanliness of the body should also be determined. The medical officer making the inspection is accompanied by an officer of the company or detachment to which the men belong. Where feasible, and when required, a monthly physical inspection may include a dental survey made by a dental officer. Where physical defects are found, appropriate action should be taken, including, for example, treatment or observation in hospital or a change of duty.

CHAPTER XXVIII.

VITAL STATISTICS

RATES, TABULATION AND GRAPHIC PRESENTATION

Vital statistics include the collection and study of certain facts regarding people, and statistical methods express in figures these facts or happenings as influenced by numerous causes. Statistical methods are invaluable and necessary in the prosecution of epidemiological studies, but only the calculation of rates, tabulation, and the graphic presentation of statistical data will be considered in this chapter.

CALCULATION OF RATES

A statistical rate is the number of times an event occurs in a definite number of people during a given period of time. Rates are used primarily to present an accurate picture of the frequencies of an event, and to express such frequencies so as to render them available for comparative purposes. For example, it may be a statistical fact that in a population of 3 million there were 36,000 deaths in 1936, but this statistical fact becomes more significant if expressed as 12 deaths per 1,000 people, or if stated as a death rate of 12 per 1,000. Moreover, when so expressed such a statistical fact can be readily compared with a similar event in any other group of people regardless of the number involved.

In order to calculate a rate, the following factors must be known:

(a) the frequencies of the event
(b) the population concerned
(c) the period of time involved.

These factors are then applied to a given population or common factor, usually 1,000. The formula is:

$$\text{Rate per 1000} = \frac{\text{Frequencies} \times 1000}{\text{Population}}$$

Annual rates are most commonly used for comparative purposes and an annual rate is obtained by multiplying the actual rate by the necessary factor. Thus, if the frequencies occurred in one day, then the rate obtained for that period is multiplied by 365 to obtain an annual rate. Or a weekly rate is multiplied by 52, and a monthly rate by 12. If the frequencies occur during a four week period, the rate for that period is multiplied by 13. If a five week period is used, then the rate for that period is multiplied by 10.4.

For example, assuming that 10 cases of measles occur during one month in a command having an average daily strength of 600 troops, the monthly rate is, of course, 10 per 600 strength. To convert the monthly rate into an annual rate it is assumed that the frequency of occurrence during the one month would continue at a constant rate during an entire year. The annual rate would then be 12 times the monthly rate, or 120 per 600 strength. To convert this rate into a rate per 1000, it is only necessary to determine how many cases would occur if the strength were 1000 instead of 600. Obviously, if 120 cases occurred among 600 troops, 200 cases would occur among 1000 troops. Therefore, the annual rate per 1000 in this situation is 200.

When the above formula is used, the calculation is made as follows:

$$\begin{aligned}\text{Annual rate per 1000} &= \frac{10 \times 1000}{600} \times 12 \\ &= \frac{10{,}000}{600} \times 12 \\ &= 16.66 \times 12 \\ &= 200\end{aligned}$$

Given another example in which twelve cases of mumps occur in one week in a command of 1450 troops the annual rate per 1000 strength would be:

$$\begin{aligned}\text{Annual rate per 1000} &= \frac{12 \times 1000}{1450} \times 52 \\ &= \frac{12{,}000}{1450} \times 52 \\ &= 8.28 \times 52 \\ &= 430.56\end{aligned}$$

Rates are applied in the army principally to deaths, admissions, and the incidence of diseases and injuries, and their calculation is required by Army Regulations 40-235, par. 6 (Venereal Report), 40-275, par. 1 (Sanitary Report), and 40-1080, par. 8 (Tables and Charts).

In the army, the population or strength is a fairly exact figure. Every unit in the army prepares a daily strength return, which is an actual count. During peace these returns are forwarded to the Adjutant General's Office. In time of war a daily message concerning the strength of a unit is sent to the highest command. As data concerning frequencies of events are obtained from register cards, weekly statistical reports and sick and wounded records, the morbidity and mortality reports for any army unit are relatively accurate.

Noneffective rate. The noneffective rate is a daily rate and is the number of men sick in hospital or quarters per 1000 strength on the day for which it is calculated. The noneffective rate is employed to determine the number of troops in a given command that are physically fit for duty on a given day, or the average daily noneffectiveness caused by a disease during a selected period of time.

The noneffective rate for a given day may be calculated as follows:

$$\text{Noneffective rate} = \frac{\text{Number of sick} \times 1000}{\text{Strength}}$$

The following formula may be used to determine the average daily noneffective rate for a period of more than one day:

$$\text{Noneffective rate} = \frac{\text{Sum of number sick daily} \times 1000}{\text{Sum of daily strengths}}$$

The following formula may also be used to determine the daily noneffective rate:

$$\text{Noneffective rate} = \frac{\text{Total days lost}}{\text{No. of days in period}} \times \frac{1000}{\text{average daily strength}}$$

Thus, if in a command of 500 troops, 10 men are sick on a given day, the noneffective rate is 20 per 1000 troops. It is calculated as follows:

$$\text{Noneffective rate per 1000} = \frac{10 \times 1000}{500} = \frac{10{,}000}{500} = 20$$

If four cases of measles occur in a command of 500 troops during one month and these cases were sick for 10, 12, 14 and 14 days, respectively, the noneffective rate may be calculated as follows:

$$\text{Noneffective rate per 1000} = \frac{(10 + 12 + 14 + 14) \times 1000}{30 \times 500} = \frac{50{,}000}{15{,}000} = 3.33$$

Or:

$$\text{Noneffective rate} = \frac{50}{30} \times \frac{1000}{500} = 1.666 \times \frac{1000}{500} = 1.666 \times 2 = 3.33$$

In 1928 the total United States army, consisting of 134,380 troops, lost 73,144 days from duty because of influenza, or, as expressed by the noneffective rate, 1.49 men out of every 1000 troops were incapacitated for duty each day of the year. This is determined by the following calculation:

$$\text{Noneffective rate per 1000} = \frac{73{,}144}{365} \times \frac{1000}{134{,}380} = 200.39 \times \frac{1000}{134{,}380} = 200.39 \times 0.00744 = 1.49$$

Ratios. A ratio is a fractional figure expressing the relationship between the frequencies of related events. The denominator used in calculating a ratio is always the frequencies of an event, and the constant used is 100. For example, if in a series of 60 cases of measles 12 of the patients develop pneumonia, the ratio is 20 cases of pneumonia to 100 cases of measles, or 1 case in 5.

A case fatality rate is actually the ratio of deaths from a specific disease to the number of people having that disease

in a given series of cases. If during an epidemic of meningococcic meningitis there are 120 cases and 30 of them die, the case fatality rate would be 25, calculated as follows:

$$\text{Case fatality rate} = \frac{30 \times 100}{120}$$
$$= 0.25 \times 100$$
$$= 25.$$

TABULATION

Tabulation may be defined as the process of arranging observations, data or other statistical information in tabular form for the purpose of consideration, study, or presentation. In epidemiological work, a statistical table is usually prepared for the purpose of arranging and presenting a series of observations or events so that the essential information to be conveyed by the table can be most readily grasped and understood by the reader.

A statistical table consists of a heading, subheadings and lines or columns of itemized data. The data included in a statistical table consist of related observations and events so classified and arranged as to show clearly and concisely the frequency of occurrence of such events or observations. A list of unrelated events does not constitute a table.

A table should be as simple in construction as possible and still convey the desired information and no more data should be included than are necessary to accomplish the purpose of the table. An extensive or involved table should not be used where two or more simpler tables will answer the same purpose.

Headings. A table heading should describe briefly and clearly the contents of the table. The main heading or title is in almost all instances placed at the top of the table. A subheading, or column heading, is placed immediately above the column to which it pertains. The column heading should be clear and brief. Abbreviations may be used, but unless they are accepted or official they should be defined in footnotes or in the text. Improperly worded headings may greatly decrease the value of a table. Examples of table headings are shown in Tables No. 1 to 5.

Arrangement of data. The best arrangement of the data in any given instance is determined largely by the purpose of the table and the character of the observations which are to be tabulated. A large number of observations may be divided into a series of groups as shown in Table No. 1. The sole purpose of this table is to show the number of admissions for disease among white enlisted men of various ages. The data could be tabulated by single years, but the table would then be long and difficult to read. Grouping the number of admissions into five year age groups will not materially impair the statistical value of the table and will render it much easier to make comparisons between ages. Five year groups are therefore used in this table.

TABLE No. 1

Number of admissions for diseases by age groups among white enlisted men in the United States in 1928.

Age (Years)	*No. of admissions*
Under 21	11,542
21-25	23,578
26-30	8,589
31-35	2,694
36-40	2,043
41-45	917
46-50	764
51-55	214
56 and over	121
Total	50,462

Table No. 2 shows a method of presenting information regarding the prevalence of influenza during the World War. The data are limited to the incidence of the disease among enlisted troops in four countries.

TABLE No. 2.

Admission rate for influenza among enlisted men in the United States, the Philippine Islands, Hawaii and Europe, April 1, 1917 to December 31, 1919.

Country	*Rate per 1000*
United States	244.27
Philippine Islands	70.86
Hawaii	61.35
Europe	137.38

Table No. 2 gives only the combined incidence rate for white and colored enlisted men in the countries concerned. In many instances of this nature it would be desirable to present more detailed information. For example, the observations or data could be classified and tabulated to show separate admission rates for white and colored troops, or admission rates by months or by age groups, or in various other ways. Each series of observations can be placed in a separate table arranged as in Table No. 2, or two or more series can be grouped in one table. In the latter case branching columns or lines are frequently used, the exact arrangement depending on the comparisons which it is desired to emphasize. Table No. 3 shows one method of comparing two series of observations in one table—the admission rates for white and for colored enlisted men.

TABLE No. 3.

Admission rate for influenza among white and colored enlisted men in the United States, Philippine Islands, Hawaii and Europe, April 1, 1917, to December 31, 1919.

Country	*Rate per 1000*	
	White	*Colored*
United States	242.62	266.51
Philippine Islands	62.08	104.35
Hawaii	62.62	55.14
Europe	119.92	152.10

Further divisions can be made and additional series included and compared in the same table. For example, Table No. 4 shows a method of incorporating four series of observations in one table, so that any one series can be compared directly with any one of the others.

TABLE No. 4.

Admission and death rates for influenza among white and colored enlisted men in the United States, the Philippine Islands, Hawaii and Europe, April 1, 1917 to December 31, 1919 (Rates per 1000).

Country	*Race*	*Admissions*	*Deaths*
United States	White	242.62	7.44
	Colored	266.51	10.74
Philippine Islands	White	62.08	0.12
	Colored	104.35	0.00
Hawaii	White	62.62	0.19
	Colored	55.14	0.60
Europe	White	119.92	3.91
	Colored	152.10	5.15

Table No. 5 illustrates another method of arranging comparable series of observations in one table. This table shows admission and death rates for white and colored troops in various camps in the states of Texas and Georgia so tabulated that the incidence or the death rates for white troops can be compared with those for colored troops or the rates for one camp can be compared with those for any one of the other camps in either state.

TABLE No. 5.

Admission and death rates for influenza among white and colored enlisted men by states and camps, April 1, 1917 to December 31, 1919. Rates per 1000.

States	*Camps*	*Admissions*		*Deaths*	
		White	Colored	White	Colored
Texas	Bowie	242.75	1253.93	2.58	48.27
	Logan	299.23	110.39	3.30	1.87
	Travis	427.66	252.54	5.57	2.58
	MacArthur	285.02	396.66	5.76	3.15
Georgia	Gordon	103.97	77.10	0.24	0.59
	Wheeler	197.48	112.40	0.29	1.10
	Hancock	235.69	423.20	14.23	16.30

GRAPHIC PRESENTATION

Graphic methods may be employed in statistical work either for the purpose of facilitating statistical studies or as a means of presenting statistical facts.

Graphic presentation is accomplished principally by the use of diagrams to compare observations, to represent the frequency of occurrence of a given event, to depict the trend of a series of events, or the geographic distribution of events.

When a table or text is used to present statistical data dealing with frequency of occurrence, the trend, or the comparable value of different observations, the reader must analyze and form a mental picture of the frequencies, trend or value of such observations in order to grasp and understand their significance. Consequently, when any but the most simple statistical data are presented in tabular or text form, they lose much of their value for purely presentation purposes because they do not attract attention and are difficult to analyze. However, when the general features of such data are depicted by graphic methods their significance can be understood and remembered with a minimum of mental effort on the part of the reader. Graphic methods are therefore of great value in reporting the results of epidemiological studies or in presenting epidemiological data.

The statistical diagrams commonly used in epidemiological work include the line diagram, bar diagram, histogram, pie diagram, and maps. The line diagram, bar diagram and histogram are usually plotted on cross section paper.

Line diagrams. Line diagrams are usually employed to show the frequency of continued occurrence of a series of events and to depict either the magnitude of the variations or the trend of events. Either arithmetical or logarithmic scales may be used.

Line diagrams drawn on cross section paper are commonly employed to demonstrate the incidence of disease. Figures No. 319 and No. 320 show the method of constructing line diagrams on arithmetical cross section paper. These diagrams depict the frequency and the difference in frequency of the events under consideration and also show the trend by arithmetical progression.

The true trend of a series of events cannot, however, be represented graphically by a scale which is graduated in arithmetical

AVERAGE ANNUAL ADMISSION RATE FOR MEASLES TROOPS IN THE U. S. 1924—1928, INCLUSIVE.

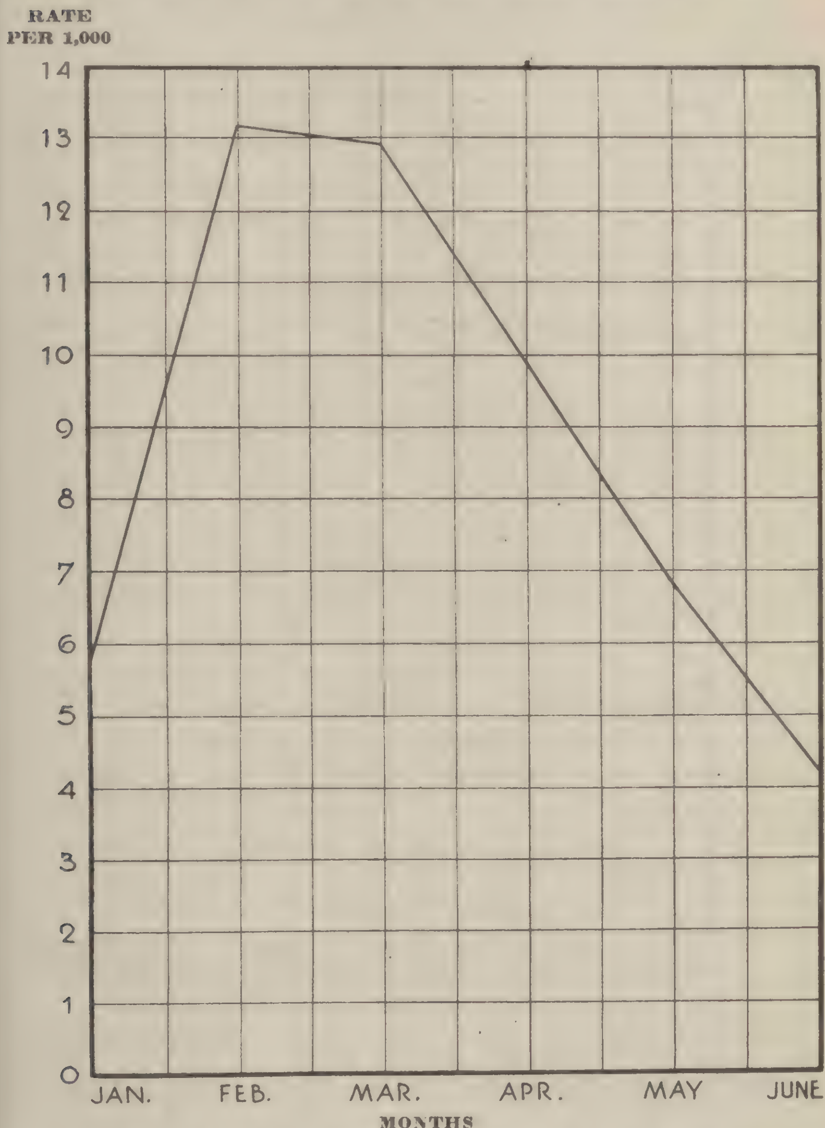


FIG. No. 319. One method of constructing a line diagram.

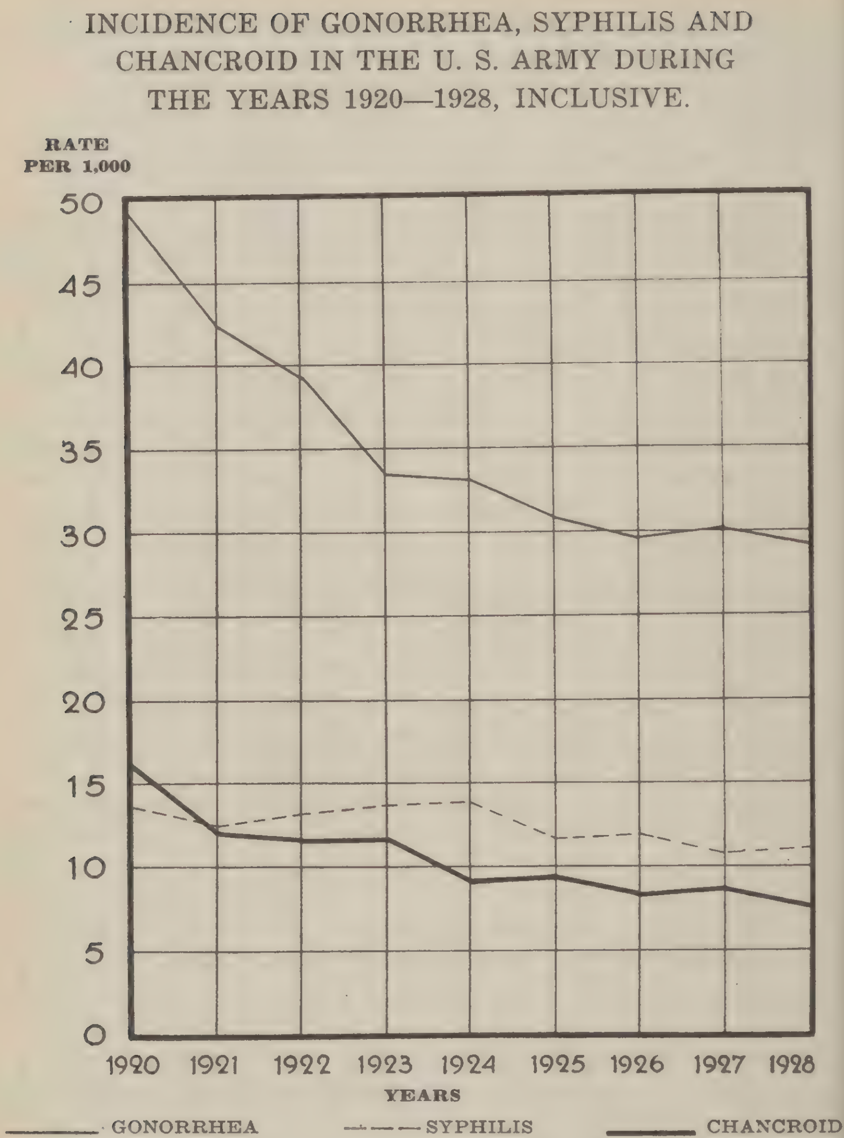


FIG. No. 320. A line diagram showing different types of curves.

progression, as it is necessary, in order to show the true trend, to depict the differences in frequency in terms of percentage. This can be done to the best advantage by the use of a horizontal arithmetical scale and a vertical logarithmic scale. Paper ruled for this purpose is known as arithmetical-logarithmic, or arith-log, grid paper (Fig. No. 322).

When the frequency of occurrence is plotted on a logarithmic scale the differences in frequency are shown graphically in terms of percentage. Thus, if two curves plotted on a logarithmic scale in the same diagram are parallel, the percentage rate of change in frequency is the same for each series, regardless of relative differences in the size of the observations or of the groups from which the observations are obtained. If one of the curves is steeper than the other, the difference in frequency, in terms of percentage, is greater in the steeper curve. On the contrary, if two curves are plotted on an arithmetical scale in the same diagram, their relation to each other in the diagram is determined by the relative size of the group from which they were obtained and the absolute number of occurrences in each group, and not by changes in percentage of occurrence. For example, Fig. No. 321 shows the admission rate per 1000 for all causes for two stations—station A and station B—during a period of six months. Station A had an admission rate of 500 per 1000 for January and station B had a rate of 300 per 1000 during the same month. Thereafter the admission rate for each station decreased at the rate of ten per cent per month for five months. In section *a* of Fig. No. 321 the frequency is plotted on arithmetical paper. While the reduction is proportionately the same for each station the curves are not parallel and visually it appears that the decrease is much greater for station A than for station B. This is due to the fact that even though there is an equal rate of decrease, the magnitude of the increments by which the rates are reduced each month is actually greater for station A than for station B. Consequently, when shown by an arithmetical scale, the curve for station A is steeper than the curve for station B, and the true trend of the admission rates for the two stations cannot be compared graphically by this method.

Section *b* of Fig. No. 321 shows the same data as section *a* plotted on logarithmic instead of on arithmetical paper. The difference in the results is quite apparent. The curves in section

CURVES OBTAINED BY PLOTTING LIKE DATA ON AN ARITHMETICAL SCALE AND ON A LOGARITHMIC SCALE.

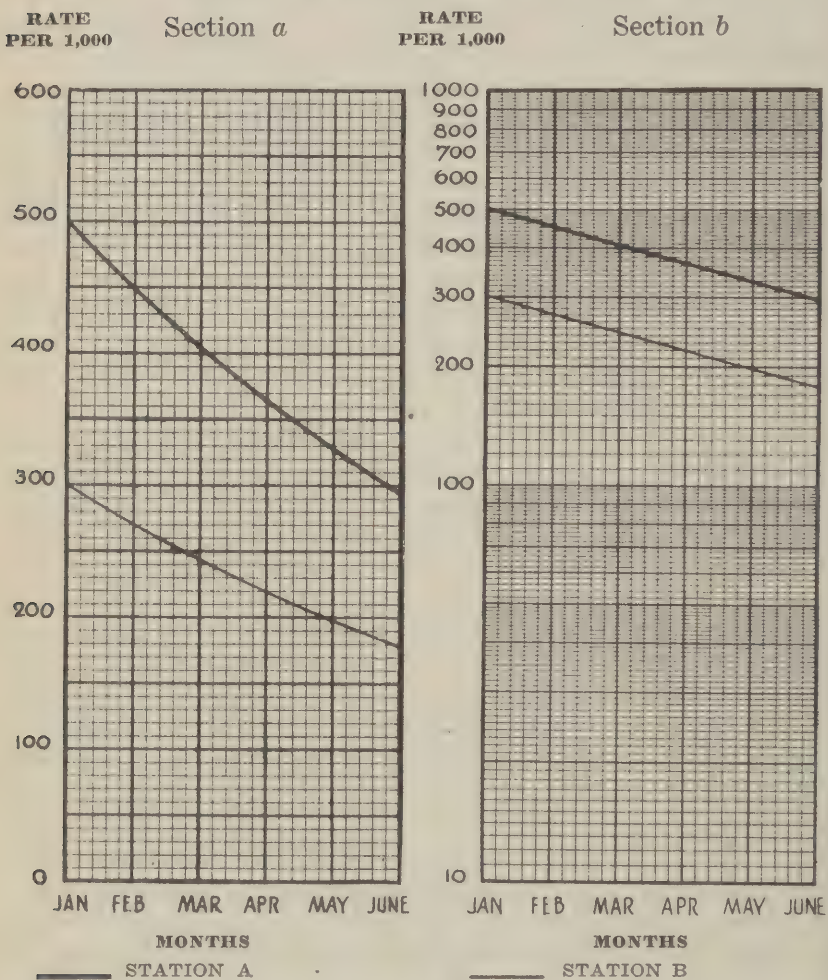


FIG. No. 321. A line diagram showing difference in curves produced by same data when plotted on arithmetical and logarithmic paper.

b show graphically the true trend of the rates and, as the rate of decrease is the same, the curves are parallel.

The practical use of the logarithmic scale in epidemiological work is demonstrated by Fig. No. 322, in which the data shown in Fig. No. 320 is plotted on arithlog instead of arithmetical paper. In Fig. No. 320 the reduction in the incidence of gonorrhea appears to be proportionately greater than the reduction in the incidence of chancroid. The incidence of gonorrhea was reduced from 48.84 per 1000 in 1920 to 29.03 per 1000 in 1928—a decrease of 19.81 per 1000, or 40.56 per cent. The incidence of chancroid was reduced from 16.23 in 1920 to 7.98 in 1928, or 50.83 per cent. While the incidence of chancroid was reduced only 8.25 per 1000 as compared with a reduction of 19.61 per 1000 for gonorrhea, nevertheless there was a decrease of 50.83 per cent in the incidence of chancroid and a decrease of only 40.56 per cent in the incidence of gonorrhea. In Fig. No. 322 the true trend of the incidence of gonorrhea and of chancroid is shown graphically and can be readily and accurately compared.

In the construction of line diagrams certain essential principles should be observed. Where an arithmetical scale is used the vertical scale should begin at zero on the base line (Figures No. 319 and 320). The magnitude is represented by the area between the curve line and the base line and where the base line does not represent zero, a true picture is not obtained. Where logarithmic paper is used the lines at the top and bottom of the diagram represent some power of ten on the logarithmic scale (Fig. No. 322).

The scales should be placed along the borders and outside of the diagram. The vertical scale is usually placed at the left and reads from the bottom to the top. The horizontal scale can be placed at either the bottom or the top of the diagram, but is usually at the bottom. It should read from left to right.

The horizontal scale should be employed to show units of time and the vertical scale the frequency of occurrence.

Nothing should be placed between the curve lines and the base line. All explanatory writing or figures should be placed either above the curve lines or outside of the borders of the diagram.

The coordinate lines should not be any more closely spaced than necessary to facilitate reading the diagram.

INCIDENCE OF GONORRHEA AND
CHANCROID IN THE U. S. ARMY
DURING THE YEARS 1920—1928, INCL.

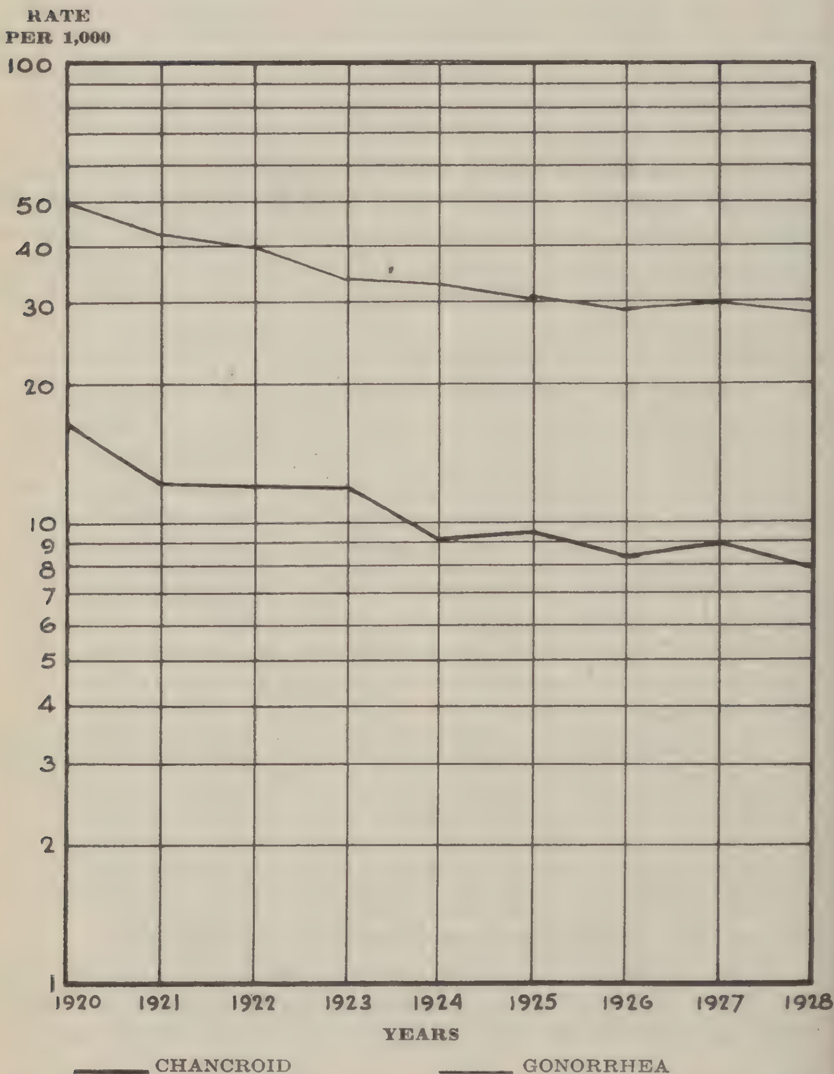


FIG. No. 322. A line diagram showing method of using logarithmic paper. (See Fig. No. 320).

The curve lines should be definitely distinguished from the other lines. The base line should be heavier than the rulings.

Where a diagram contains a number of curve lines they should all be black in color and distinguished from each other by differences in thickness or by the use of broken lines or dotted, or dot-dash lines (Fig. No. 320). Colored lines can be used, but are not as effective as black lines. If there is more than one curve line, the legend or explanatory notes should state definitely the purpose of each line (Fig. No. 320).

The title of the diagram should be clearly and concisely worded. It should be placed outside the borders of the diagram and may be either above or below the diagram—preferably above. Subheadings or legends should be used for each scale.

Bar diagrams. The bar diagram is a simple and, within the limits of its application, a very effective method of depicting statistical observations. It consists, as shown in Fig. No. 323, of bars, the length of which represents the magnitude of the event in question. The bars may be solid or open, or they may be made with single or double cross hatching or other markings (Fig. No. 326). The bars are usually horizontal, but may be vertical.

Bar diagrams can be used most satisfactorily to illustrate graphically, for purposes of comparison, the magnitude of separate events of a similar nature and when so used the base line must be zero, and the scale uniform. Where the events to be shown vary continuously, a line diagram should be used. Thus, in Fig. No. 324 each bar represents the noneffective rate for each 1000 white enlisted men during 1928 in the country to which it pertains. In each instance the event shown by a bar is a distinct and separate entity. On the contrary, in Fig. No. 319, a line diagram is used to depict the incidence of measles in the army in the United States during a period of six months. Here the variation in rate is continuous throughout the time period and there are no separate entities. While a bar diagram could be used to show the incidence during each month as a separate item, the continuous line presents a more accurate and a more graphic picture.

Usually, a horizontal scale is used to represent the magnitude of the bars, but figures may be employed with or without a scale. If a scale is used, it is usually placed at the top of the diagram.

ANNUAL DISCHARGE RATES FOR ALL CAUSES PER 1,000 TOTAL MILITARY PERSONNEL BY CORPS AREAS AND DEPARTMENTS IN 1928.

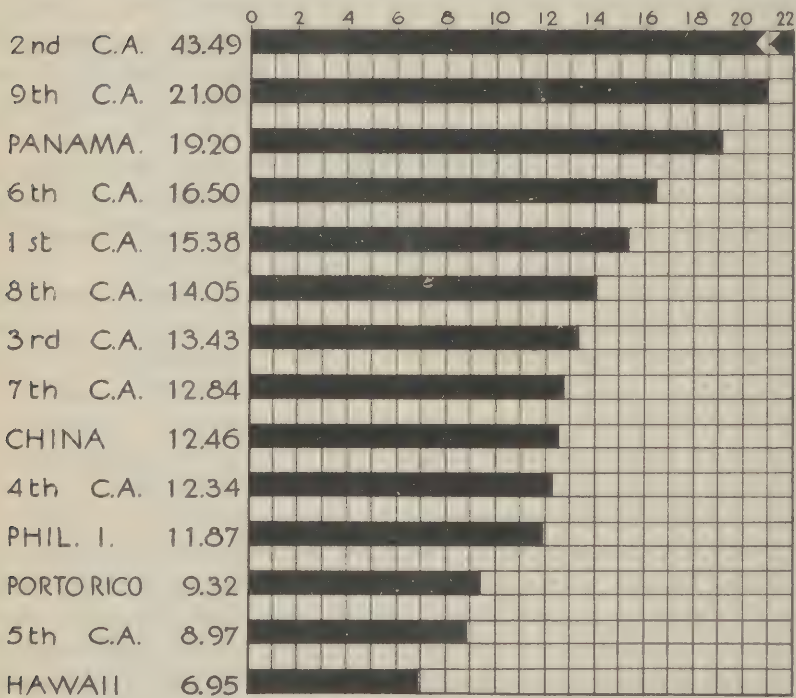


FIG. No. 323. A method of constructing a bar diagram. Note that the upper bar is too long for the diagram and has been broken.

ANNUAL NONEFFECTIVE RATES FOR DISEASES PER 1,000 WHITE ENLISTED MEN BY COUNTRY IN 1928.

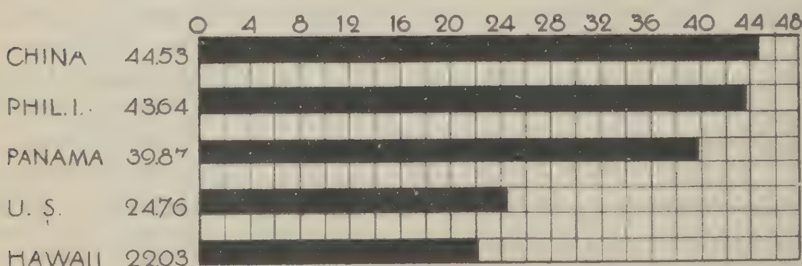


FIG. No. 324. A method of constructing a simple bar diagram.

If a bar diagram is to be employed solely for graphic presentation the area within the borders of the diagram should contain only the bars. If figures representing the actual magnitude of the individual bars are used, they should be placed outside the borders of the diagram opposite the end of the bars on either the right or left side. All legends, or explanatory notes, should be placed outside the diagram proper and nothing should be inserted between the bars or between the ends of the bars and the side of the diagram.

However, a bar diagram may be employed to present data for analysis and study, as well as for graphic purposes. Under these conditions words or figures may be placed in the bars or within the diagram outside of the bars. While this method of construction may reduce the graphic value of the diagram, it affords a valuable means of presenting a great deal of information in a highly condensed form. It will also frequently obviate the necessity for using tables or additional diagrams, and the consequent undesirable separation of comparable data (Fig. No. 325).

ANNUAL NONEFFECTIVE AND DISCHARGE RATES FOR DISEASES PER 1,000 WHITE ENLISTED MEN BY COUNTRY 1928.

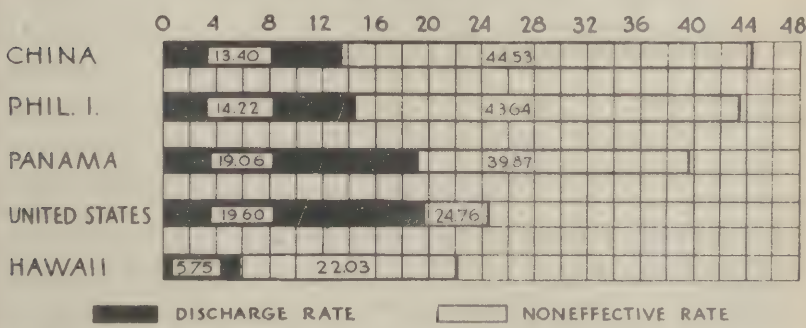


FIG. No. 325. Bar diagram showing method of using two types of bars and the inclusion of data in the bars.

If the relative magnitude of one of a number of items is so great that the bar is too long to be included in the diagram without unduly shortening the other bars, the bar representing that one item may be broken and its magnitude represented by figures, as shown in Fig. No. 323, or Fig. No. 20,

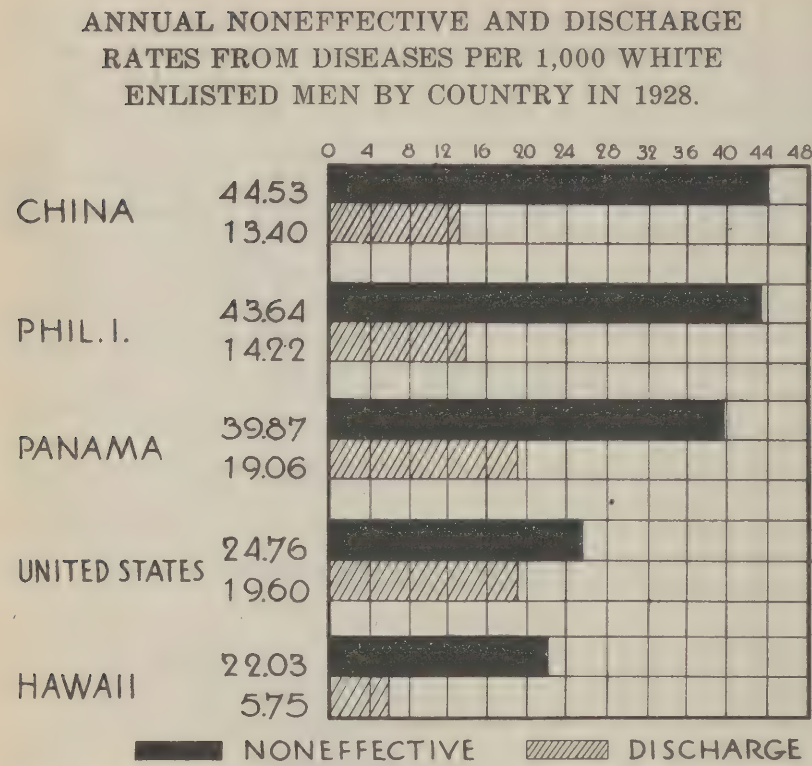


FIG. No. 326. The bar diagram showing the use of the solid bar and the cross-hatched bar in same diagram.

page 158. This procedure impairs the graphic value of the diagram and should not be used if it can be avoided.

All the bars in a diagram should have a common base and there should be a separate bar for each event depicted. Combined bars can be used to show two or more series of events where the magnitude of each item of one series is less than the corresponding item in another series (Fig. No. 325). A diagram in which combined bars are used is, however, more difficult to read and much less effective than one consisting of separate bars and should not be utilized for graphic purposes unless it is necessary to conserve space.

The title of a bar diagram may be placed at either the top or bottom of the diagram.

DISTRIBUTION BY WEIGHT GROUPS OF 783 RECRUITS WHO HAD PULMONARY TUBERCULOSIS AND WHOSE HEIGHT WAS 65 INCHES.

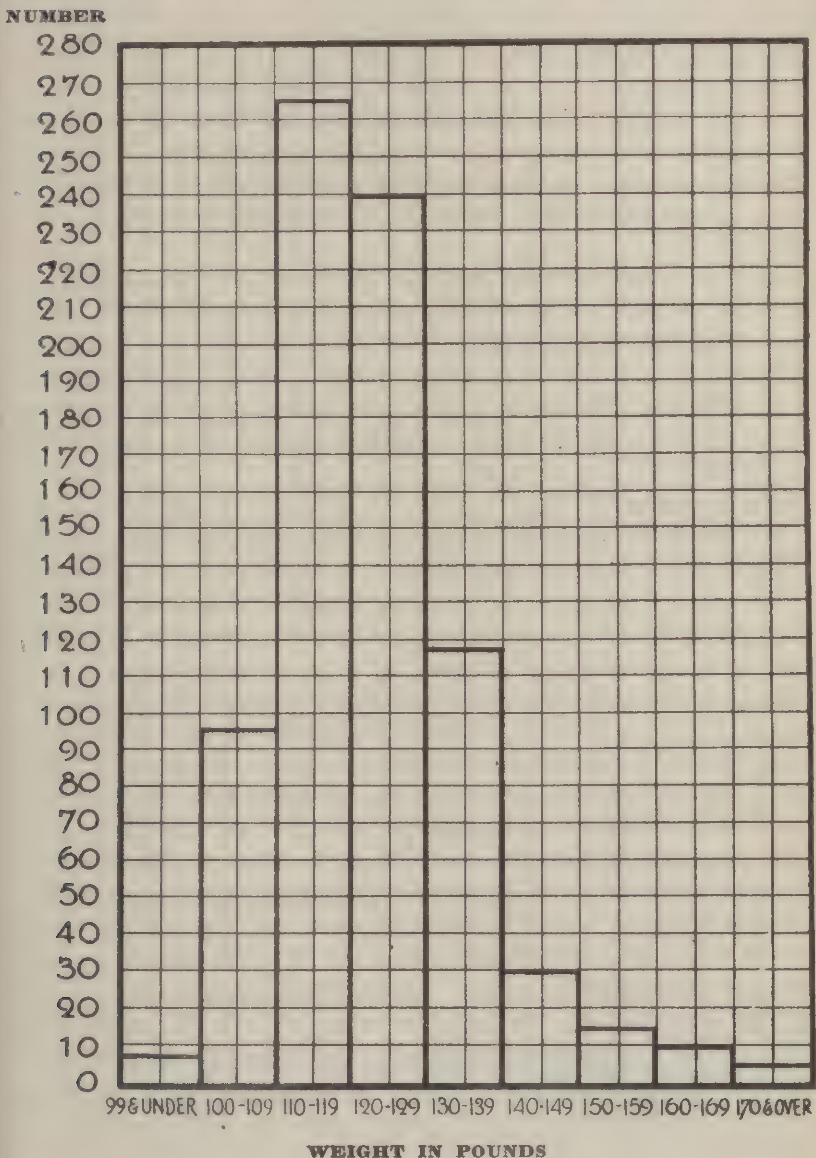


FIG. No. 327. Method of constructing a histogram.

Histograms. The histogram affords an accurate and effective method of showing the frequency distribution of groups of related events. The horizontal scale represents units, groups or classes of equal size, while the vertical scale indicates the frequency. The histogram in Fig. No. 327 shows the frequency distribution by weight groups of 783 recruits who had pulmonary tuberculosis and who were 65 inches in height. Obviously, it is not practicable or necessary to show the frequency by one pound class units, so some kind of grouping must be made. In Fig. No. 327 a class unit of ten pounds is used. Some other unit, such as five pounds, could have been selected.

Fig. No. 328 shows another method of constructing a histogram, which differs from that shown in Fig. No. 327 only in the omission of the interior vertical lines.

The title of a histogram may be placed at either the top or the bottom. The horizontal scale should be at the bottom of the diagram. No writing or figures should be placed within the borders of the diagram.

Pie diagrams (Fig. No. 329). The pie diagram can be used for the same purpose as a bar diagram, but is generally considered to be of much less value. It can be employed to the best advantage in epidemiological reports to show the proportionate value of each of a series of observations in terms of percentage. In such a diagram, the total value of the circumference is 100 per cent. For example, there were 75,661 admissions to sick report for disease among the American troops during 1928. The percentage of the total number of admissions occurring among the troops of each arm and service of the army is shown graphically in Fig. No. 329 by means of a pie diagram. The distance along the circumference which is given to each event is determined by the percentage which that event is of the sum of events represented by the diagram. Thus, in Fig. No. 329 there were 5393 admissions among Medical Department troops. These 5393 admissions constitute 7.13 per cent of the total number (75,661). The proportion of the admissions which are from Medical Department troops is therefore indicated on the diagram by a distance along the circumference of 7.13 per cent of 360 degrees, or 26 degrees.

DISTRIBUTION BY WEIGHT GROUPS OF 783 RECRUITS WHO HAD PULMONARY TUBERCULOSIS AND WHOSE HEIGHT WAS 65 INCHES.

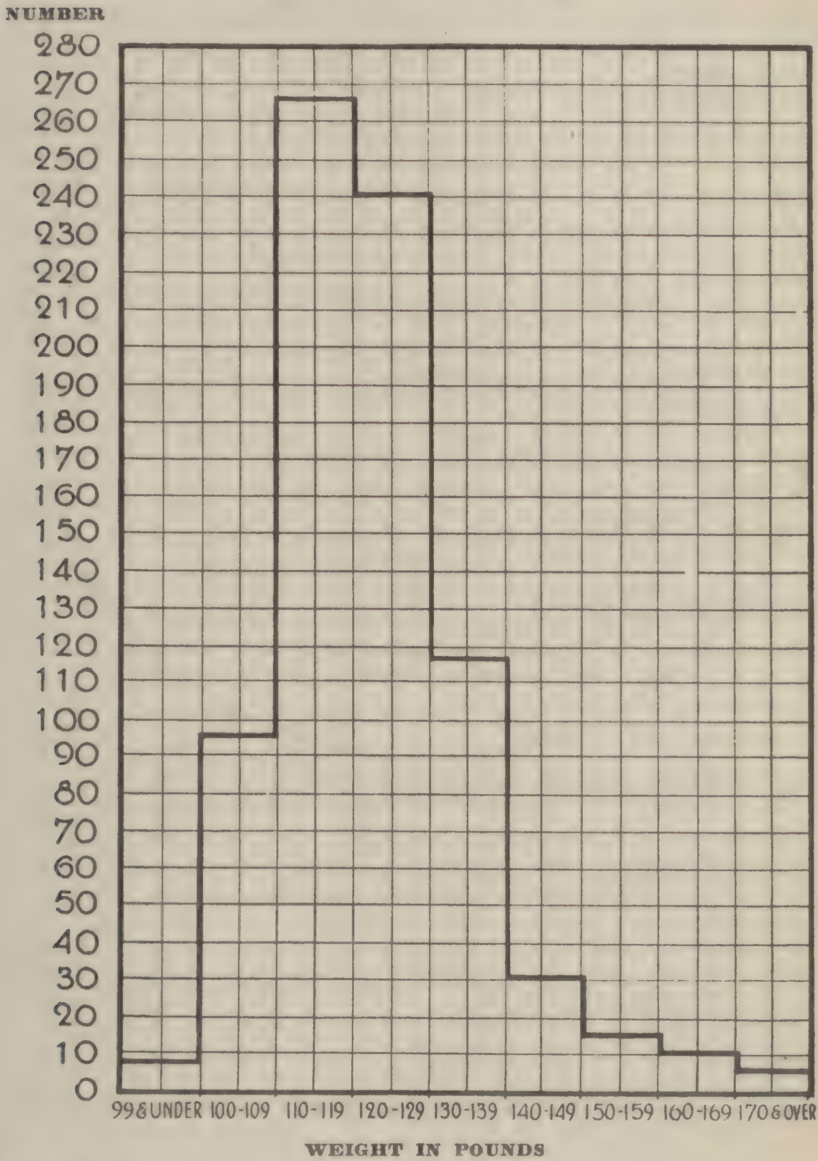


FIG. No. 328. Method of constructing a histogram without the interior **vertical lines.**

NUMBER OF ADMISSIONS FROM DISEASES
U. S. ARMY BY ARMS AND SERVICES 1928.

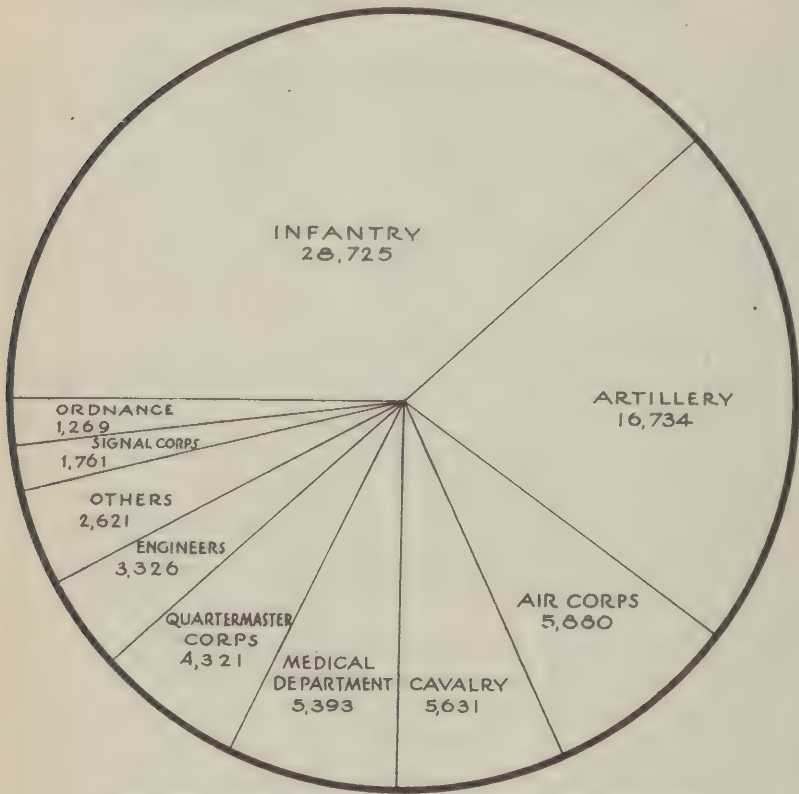


FIG. No. 329. Method of constructing a pie diagram.

APPENDIX I.

FACTORS TO BE CONSIDERED IN SURVEY OF A RAPID SAND FILTRATION PLANT.

NAME OF PLANT ....
LOCATION .... STATION .... CITY........ COUNTY........
INSPECTED BY ....
INFORMATION OBTAINED FROM ....
PLANT IN CHARGE OF ....
Weather on day of inspection and few days previous...................
Gallons filtered daily ....Rated capacity ....
Hours plant is usually operated ....Source of supply ....
Population supplied ....No. consumers ....
PUMP STATION—Raw water pumps-No. .... No. in use ....
Hours usually operated ....
Type and capacity of pumps ....
Filtered water pumps-No......... No. in use ....
Type and capacity of pumps...
RAW WATER. Turbidity: .... Hardness ....
Reaction .... Color...............
SETTLING BASINS OR RESERVOIRS (without coagulation).
Number .... Capacity of each.............................
Date last cleaned .... Appearance of water................
COAGULATION BASINS: Number .... Type..................
....
Normal detention period .... Actual detention period ....
Approximate rate of flow ....Date last cleaned ....
Appearance of water .... Reaction of water ....
Character of floc ....
COAGULANTS: Kind .... Amount used ....
Type and condition of apparatus ....
Method of mixing .... Point of application ....
Turbidity of coagulated water ....
Soda ash: Amount .... Method of application ....
....
LIME: Quantity .... Method of application ....
RECARBONATION: Methods ....
ACTIVATED CARBON: Quantity .... Method of application ....
FILTER UNITS: Number .... Size ....
Structural features ....
Depth of gravel .... Depth of sand ....
Height of top of water troughs above sand ....

Filter No.	Hours since washed	Loss of head		Wash water		Condition of sand
		Before washing	After washing	Time of washing	Method of washing	
1.						
2.						
3.						
4.						
5.						
6.						

Controllers in use .... Condition ....
CLEAR WATER BASIN—Protection against contamination ....
Appearance of water ....
CHLORINATION .... Gallons treated per day ....
Maximum .... Minimum .... Average ....
Calcium Hypochlorite: Kind ....
Pounds per 24 hours ....
Per cent available chlorine ....
Method of mixing ....
Size of mixing tank ....
Capacity solution tanks .... No. tanks ....
Strength of solution ....
Application controlled by ....
Liquid chlorine
Pounds of chlorine per 24 hours ....
Application
Point of application ....
Period of reaction—minutes ....
Make of machine ....
Solution or dry feed ....Gravity or injector feed ....
Manual or automatic control ....
Condition of apparatus ....
....
What tests of apparatus made by operator and how often ....
....
Test for residual chlorine p.p.m. ....Sample point ....
Reserve chemical supply ....
AMMONIA: Quantity ....
Point of application ....
Method of application ....
RESERVOIRS.
Capacity .... Gallons usually in storage ....
Methods of protecting ....
Condition of reservoir ....
Appearance of water ....

TESTS.

pH values ....

Alkalinity ....

Turbidity ....

Color ....

CO_2 ....

What tests made by the operator and how often ....

GENERAL REMARKS ....

....

____

____

APPENDIX II.*

NUTRIENT CONSTITUENT CONTENT AND CALORIC VALUE OF THE COMMON FOODS
(Edible Portions)

Food	Protein per cent	Fat per cent	Carbo-hydrate per cent	Fuel value per lb. calories
Meats				
Beef,				
Chuck	19.2	15.4	—	978
Corned	15.6	26.2	—	1353
Dried, salted and smoked	30.0	6.5	.4	817
Fore quarter, lean	18.9	12.2	—	842
Fore shank, lean	22.0	6.1	—	647
Hind quarter, lean	20.0	13.4	—	907
Hind shank, lean	21.9	5.4	—	617
Liver	20.4	4.5	1.7	584
Loin	19.7	12.7	—	877
Porterhouse steak	21.9	20.4	—	1230
Ribs, lean	19.6	12.0	—	845
Round, lean	21.3	7.9	—	709
Round, free from visible fat	23.2	2.5	—	512
Rump, lean	20.9	13.7	—	940
Sides, lean	19.3	13.2	—	890
Sirloin steak	18.9	18.5	—	1099
Tenderloin	16.2	24.4	—	1290
Tongue	18.9	9.2	—	717
Lamb, breast	19.1	23.6	—	1311
Chops, broiled	21.7	29.9	—	1614
Fore quarter	18.3	25.8	—	1385
Hind quarter	19.6	19.1	—	1149
Leg, roast	19.7	12.7	—	876
Side	17.6	23.1	—	1263
Mutton, fore quarter	15.6	30.9	—	1543
Hind quarter	16.7	28.1	—	1450
Leg	19.8	12.4	—	863
Side	16.2	29.8	—	1512
Pork, chops, medium	16.6	30.1	—	1530
Bacon, smoked	10.5	64.8	—	2840
Chuck ribs and shoulder	17.3	31.1	—	1585
Fat, salt	1.9	86.2	—	3555
Ham, fresh, lean	25.0	14.4	—	1042
Smoked, lean	19.8	20.8	—	1209
Lard, refined	—	100.0	—	4082
Sausage	13.0	44.2	1.1	2030
Sausage, bologna	18.7	17.6	.3	1061
Side	9.1	55.3	—	2423
Tenderloin	18.9	13.0	—	875
Veal, breast	20.3	11.0	—	817
Cutlet	20.3	7.7	—	683
Fore quarter	20.0	8.0	—	690
Hind quarter	20.7	8.3	—	715
Side	20.2	8.1	—	697

* Compiled chiefly from Bulletin, No. 28, Office of Experiment Stations, U. S. Department of Agriculture, modified and abridged.

Food	Protein per cent	Fat per cent	Carbo-hydrate per cent	Fuel value per lb. calories
Fowl				
Chicken, broilers	21.5	2.5	—	493
Turkey	21.1	22.9	—	1320
Fish				
Bluefish	19.4	1.2	—	402
Cod, salted	25.4	.3	—	473
Haddock	17.2	.3	—	324
Halibut steaks	18.6	5.2	—	550
Herring, smoked	36.9	15.8	—	1315
Mackerel, salted	21.1	22.6	—	1305
Oysters, in shell	6.2	1.2	3.7	235
Oysters, canned	8.8	2.4	3.9	340
Salmon, canned	21.8	12.1	—	915
Tuna	26.6	11.4	—	946
Whitefish	22.9	6.5	—	680
Dairy Products				
Butter	1.0	85.0	—	3491
Cheese, full cream	25.9	33.7	2.4	1890
Swiss cheese	27.6	34.9	1.3	1945
Milk, condensed, sweetened	8.8	8.3	54.1	1480
Skimmed	3.4	.3	5.1	167
Whole	3.3	3.8	5.0	310
Cream	2.5	18.5	4.5	883
Eggs				
Hen's eggs	13.4	10.5	—	672
Vegetable Foods, Cereals, etc				
Bread:				
Average white	9.2	1.3	53.1	1182
Whole wheat	9.7	.9	49.7	1113
Doughnuts	6.7	21.0	53.1	1941
Crackers (soda)	9.8	9.1	73.1	1875
Cornmeal	9.2	1.9	75.4	1620
Oatmeal	16.1	7.2	67.5	1811
Rice	8.0	.3	79.0	1591
Flour:				
Wheat, patent baker's grade	13.3	1.5	72.7	1623
Wheat, straight grade	10.8	1.1	74.8	1608
Wheat, average high & medium	11.4	1.0	75.1	1610
Hominy	8.3	.6	79.0	1609
Sugar	—	—	100.0	1815
Molasses, cane	2.4	—	69.3	1302
Vegetables				
Asparagus, cooked	2.1	3.3	2.2	213
Beans, dried	22.5	1.8	59.6	1565
Beans, lima, dried	18.1	1.5	65.9	1586
Beans, lima, fresh	7.1	.7	22.0	557
Beans, string, fresh	2.3	.3	7.4	184
Beets, cooked	2.3	.1	7.4	180
Cabbage	1.6	.3	5.6	143
Carrots, fresh	1.1	.4	9.3	204
Cauliflower	1.6	.5	4.7	139
Celery	1.1	.1	3.3	84
Chard	3.2	.6	5.0	173
Corn, green	3.1	1.1	19.7	440

Food	Protein per cent	Fat per cent	Carbo-hydrate per cent	Fuel value per lb. calories
Cucumbers	.2	.2	3.1	79
Egg plant	1.2	.3	5.1	126
Lettuce	1.2	.3	2.9	87
Onions, fresh	1.6	.3	9.9	220
Parsnips	1.6	.5	13.5	294
Peas, dried	24.8	1.0	62.0	1611
Peas, green	7.0	.5	16.9	454
Potatoes, white	2.2	.1	18.4	378
Potatoes, sweet	1.8	.7	27.4	558
Pumpkins	1.0	.1	5.2	117
Radishes	1.3	.1	5.8	133
Spinach, fresh	2.1	.3	3.2	109
Rhubarb	.6	.7	3.6	105
Squash	1.4	.5	9.0	209
Tomatoes, fresh	.9	.4	3.9	104
Turnips	1.3	.2	0.1	178
Vegetables, canned				
Beans, baked	6.9	2.5	19.6	583
Corn, green	3.1	1.1	19.7	459
Peas	3.6	.2	9.8	252
Pea soup	3.6	.7	7.6	232
Tomatoes	1.2	.2	4.0	103
Fruits (fresh)				
Apples	.4	.5	14.2	285
Apricots	1.1	—	13.4	263
Bananas	1.3	.5	22.0	447
Cherries	1.0	.8	16.7	354
Cranberries	.4	.6	9.9	212
Currants	1.5	—	12.8	250
Grapes	1.3	1.6	19.2	437
Grapefruit	.6	.1	12.2	235
Lemons	1.0	.7	8.5	201
Oranges	.8	.2	11.6	233
Pears	.6	.5	14.1	288
Plums	1.0	—	20.1	383
Raspberries, red	1.0	—	12.6	247
Peaches	.7	.1	9.4	188
Strawberries	1.0	.6	7.4	169
Watermelons	.4	.2	6.7	136
Fruits (canned)				
Apricots	.7	—	15.7	295
Cherries	1.1	.1	21.1	407
Peaches	.7	.1	10.8	213
Fruits (dried)				
Apples	1.3	2.0	59.6	1190
Apricots	3.7	.9	56.5	1130
Dates	1.6	2.5	70.7	1415
Figs	3.4	.3	67.0	1290
Prunes	1.6	—	66.1	1230
Raisins	2.0	3.0	68.7	1410
Miscellaneous				
Chocolate	12.9	48.7	30.3	2625
Gelatin	88.7	.1	—	2125
Oleomargarin	1.2	78.9	—	3335

APPENDIX III.

FOODS SERVING AS SOURCES OF PROTEIN AND CERTAIN MINERAL ELEMENTS

The following tables give in alphabetical order a list of foods with the approximate content of protein, phosphorus, calcium, iron, copper and manganese.

All the data contained in these tables have been taken from "Food and Health" by Henry C. Sherman (1935) and republished by permission of The Macmillan Company, publishers (page 1116).

Food	Percentage of Edible Portion			Parts per Million of Edible Portion		
	Protein	Phosphorus	Calcium	Iron	Copper	Manganese
Almonds	21.0	0.451	0.230	39.	12.1	19.4
Apples	0.3	0.012	0.008	3.5	1.2	0.25
Apricots, fresh	1.0	0.024	0.013	6.		
Artichoke, French	2.9	0.094	0.040	9.5		3.6
Asparagus	2.2	0.040	0.026	10.	1.2	1.0
Avocado	1.8	0.044	0.045	63.		
Bacon	10.5	0.096	0.010	13.		0.08
Bananas	1.2	0.030	0.008	6.4	2.2	4.6
Beans, dried	22.5	0.483	0.158	79.	9.3	15.5
Lima, dried.	18.1	0.347	0.071	86.	8.1	16.6
fresh	7.5	0.133	0.028	24.		
snap or string	2.4	0.051	0.050	10.	1.0	3.3
Beef, lean	19.7	0.204	0.013	30.	1.2	0.16
Beets	1.6	0.037	0.024	8.5	1.4	6.4
Beet greens	2.0	0.040	0.094	32.4	1.1	13.2
Blackberries	1.2	0.034	0.017	9.		
Blueberries	0.6	0.020	0.025	9.		44.
Bluefish	19.4	0.235	0.023			
Bread, white, avg.	9.2	0.097	0.031	8.	2.	
Broccoli.	3.3	0.059	0.122	13.7	0.2	
Brussels sprouts	4.4	0.121	0.027	11.7		
Butter	0.8	0.017	0.016	2.		0.4
Cabbage	1.4	0.026	0.045	4.3	1.1	0.8
Cantaloupe	0.6	0.016	0.017	3.9		0.4
Carrots	1.2	0.038	0.046	6.2	1.0	1.2
Cashew nuts	19.1	0.480	0.048			
Cauliflower	2.4	0.059	0.102	9.4	1.7	1.8
Celery	1.3	0.048	0.068	6.2	1.0	1.75
Chard, leaves	2.6	0.040	0.087	30.9		
Cheese	24.4	0.701	0.930	13.	0.45	1.07
Cherries	1.1	0.030	0.019	4.	1.6	
Chestnuts	5.5	0.094	0.032	7.		36.7
Chocolate	12.9	0.453	0.091	27.		30.5
Clams, round	10.6	0.116	0.106			
soft, long	13.6	0.105	0.123			
Coconut, fresh	5.7	0.074	0.024			13.7
Cod	16.7	0.187	0.010	3.7	3.8	0.13
Collards	4.0	0.074	0.202	16.6		

Food	Percentage of Edible Portion			Parts per Million of Edible Portion		
	Protein	Phosphorus	Calcium	Iron	Copper	Manganese
Corn meal	9.2	0.152	0.016	9.		
sweet	3.7	0.103	0.006	4.7		1.5
Cranberries	0.4	0.010	0.012	4.4	2.	4.5
Cucumbers	0.7	0.026	0.016	3.3	2.3	1.5
Currants, dried	2.4	0.195	0.082	40.		
fresh	1.6	0.038	0.026	6.3		
Dandelion greens	2.7	0.045	0.063	30.5		
Dates	2.1	0.049	0.071	35.6	2.4	38.7
Eggs	13.4	0.224	0.062	29.	1.87	0.33
Egg white	12.3	0.015	0.013	1.		
Egg yolk	15.7	0.592	0.130	86.	4.15	1.3
Eggplant	1.1	0.023	0.011	5.	0.84	1.57
Endive	1.6	0.039	0.104	12.3		2.2
Escarole	1.3	0.029	0.027	15.3		
Farina	11.0	0.125	0.021	8.		4.5
Figs, dried	4.3	0.116	0.161	28.7		
fresh	1.4	0.036	0.053			
Flounder ("sole")	14.2	0.163	0.036	7.	1.8	0.18
Flour, buckwheat	6.4	0.176	0.010	12.		20.9
Graham	13.3	0.306	0.035	35.		42.8
white	11.4	0.106	0.016	13.	2.	7.
Grapefruit	0.5	0.020	0.021	2.7		
Grapes	1.4	0.035	0.019	7.3	1.2	
Halibut	18.6	0.200	0.008	9.5	1.8	0.10
Ham	15.3	0.151	0.023	14.		
Huckleberries	0.6	0.020	0.025	9.		44.
Kale, leaves	3.9	0.072	0.197	25.4		5.
Kohlrabi	2.1	0.044	0.077	6.1		
Lamb	19.6	0.222	0.015	16.		0.37
Leeks	2.5	0.056	0.058	6.5		0.36
Lemon	0.9	0.018	0.036	6.		0.40
Lemon juice	0.6	0.010	0.023			
Lentils, dry	25.7	0.383	0.102	86.	6.6	
Lettuce	1.2	0.042	0.027	7.	2.5	9.1
Liver	20.	0.368	0.011	82.		
Macaroni	13.4	0.144	0.022	12.		
Mackerel	18.7	0.273	0.011	8.7	2.6	0.20
Milk, cows'	3.3	0.093	0.118	2.	0.25	0.03

Food	Percentage of Edible Portion			Parts per Million of Edible Portion		
	Protein	Phosphorus	Calcium	Iron	Copper	Manganese
Molasses, genuine	2.4	0.030	0.258	73.		4.2
Mushrooms		0.098	0.014	7.3		0.8
Mutton	19.8	0.216	0.015			
Oatmeal	16.4	0.422	0.063	38.		45.
Okra	1.8	0.062	0.072	6.3	1.2	6.2
Olives	1.4	0.014	0.122	29.	2.8	0.55
Onions	1.4	0.045	0.035	4.8	1.3	1.2
Orange	0.9	0.020	0.026	5.2	1.3	0.3
Orange juice	0.6	0.013	0.019	2.4	0.8	
Oysters	6.0	0.155	0.052	73.		
Parsnips	1.5	0.076	0.060	7.7		
Peaches	0.5	0.021	0.010	3.3		1.1
Peanuts	25.8	0.395	0.067	20.		
Pears	0.7	0.017	0.014	3.2	1.0	0.6
Peas, dried	24.6	0.400	0.084	57.	7.4	27.7
fresh	6.7	0.127	0.028	20.7		
Pecans	9.6	0.335	0.089	26.		34.8
Peppers, green	1.2	0.023	0.008	4.		1.4
Pineapple	0.4	0.017	0.008	3.7	1.7	3.
Plums	0.7	0.027	0.020	5.6		0.74
Pork, lean	20.	0.198	0.009	15.		0.59
Potatoes	2.0	0.058	0.012	9.1	1.3	1.4
Poultry, average	20.	0.222	0.015			0.4
Prunes, dried	2.1	0.085	0.058	28.5	4.1	1.8
Pumpkin	1.2	0.046	0.023	9.3	1.1	0.37
Radishes	1.2	0.031	0.031	8.3	3.8	0.52
Raisins	2.6	0.132	0.060	29.9		
Raspberries	1.3	0.052	0.049	8.8		5.1
Rhubarb	0.5	0.018	0.044	5.6		1.5
Rice, brown	8.0	0.290	0.084	20.	3.	17.
white	7.2	0.099	0.011	9.		10.
Salmon	20.	0.245	0.010	8.6	2.0	0.14
Shrimp	19.3	0.171	0.096		15.7	0.29
Spinach	2.3	0.040	0.077	25.5	0.72	7.4
Squash, summer	0.6	0.016[1]	0.018[1]	3.5	0.79	1.43
winter	1.5	0.028	0.019	5.5		
Strawberries	0.8	0.028	0.038	6.8		
Sweetpotatoes	1.8	0.045	0.020	7.7	0.2	4.4

Food	Percentage of Edible Portion			Parts per Million of Edible Portion		
	Protein	Phosphorus	Calcium	Iron	Copper	Manganese
Tomato	1.0	0.026	0.010	4.4	0.8	1.2
Tomato juice	1.0	0.015	0.007			
Turnips	1.1	0.047	0.060	5.2	4.0	0.8
Turnip greens	2.9	0.049	0.347	34.8	0.87	14.2
Veal	20.5	0.219	0.013	25.		0.28
Walnuts	17.5	0.358	0.089	21.		
Watercress	1.7	0.052	0.157	29.7	1.5	5.4
Watermelon	0.5	0.013	0.008	2.3		
Wheat, entire	12.5	0.374	0.053	50.	7.2	32.
breakfast foods						
"dark," avg.	12.0	0.347	0.039	45.		24.
"refined"	11.0	0.125	0.021	8.		4.5

APPENDIX IV.

SOURCES OF VITAMINS

The following table shows the relative merits of different foods as sources of Vitamins A, B, C, and G.

+ indicates that the food is an appreciable source of the vitamin.
++ indicates that the food is a good source of the vitamin.
+++ indicates that the food is an excellent source of the vitamin.
— indicates that the food furnishes no appreciable amount of the vitamin.
? indicates doubt as to vitamin value.
* indicates that evidence is lacking or appears insufficient.

It will be noted that the plus signs do not necessarily indicate relative concentrations alone.

Food	Vitamin A	Vitamin B	Vitamin C	Vitamin G
Almonds	+	++	*	*
Apples	+	+ to ++	++	++
Apricots	++	*	++	*
Artichoke, French	++	+	+	*
Asparagus	variable	+++ ?	++	+++ ?
Avocado (Alligator pear)	++	+++	+	++
Bacon	– to +	+ to ++	?	++
Bananas	+ to ++	+ to ++	++	++
Barley, whole	+	++	–	+
Beans, kidney	+	++	*	*
Beans, navy, dry or canned	+	++	*	*
Beans, sprouted	+	++	++	*
Beans, string	++	++	++	*
Beef	+	++	– to +	++
Beef fat	++	–	–	–

NOTE: From "Food and Health" by Henry C. Sherman (1935) and republished by permission of The Macmillan Company, publishers.

Foods as Sources of Vitamins A, B, C, and G (*Continued*)

Food	Vitamin A	Vitamin B	Vitamin C	Vitamin G
Beef juice	*	+	− to +	+*
Beet leaves	++	++	*	+++
Beet stems	*	+	*	++
Beets (roots)	+	+	+	+
Brains	+	++	*	*
Brazil nuts	+	++	*	++
Bread, white, water	?	+	−	?
Bread, white, milk	+	+	− to +	+
Bread, whole wheat, water	+	+++	?	+
Bread, whole wheat, milk	++	+++	− to +	++
Broccoli	++	++	+	++
Butter	+++	−	−	−
Buttermilk	+	++	+ variable	+++
Butternuts	+	++	*	*
Cabbage, green, raw	++	++	+++	++
Cabbage, head, raw	+	++	+++	++
Cabbage, head, cooked	+	++	+	++
Cabbage, head, canned	+	++	+	*
Cantaloupe	++	++	+++	++
Carrots	+++	++	++	++
Cauliflower	+	++	+	++
Celery, bleached stems	− to +	++	++	*
Celery, bleached leaves	+	++	*	*
Celery, green leaves	++	++	*	*
Chard	++	+ to ++	*	*
Cheese, whole milk	++ to +++	*	*	*
Cheese, cottage (skim)	+	*	*	*
Cherries	++	+	++	*
Chestnuts	*	+	*	+
Chinese cabbage	++	++	+++	++
Clover, young	+++	++	*	*
Coconut	+	++	*	++
Coconut oil	− to +	−	−	−
Codliver oil	+++	−	−	−
Collards	+++	++	++	++
Corn (maize), white	+	++	−	+
Corn (maize), yellow	++	++	−	+
Corn meal	− to +	+	−	*
Corn oil	+	−	−	−
Cottonseed (flour or meal)	+	++	*	++
Cottonseed oil	?	−	−	−

Foods as Sources of Vitamins A, B, C, and G (*Continued*)

Food	Vitamin A	Vitamin B	Vitamin C	Vitamin G
Cranberry (or juice)	+	–	++	–
Cream	+++	++	+ variable	+++
Cress	+++	++	+++	++
Cucumber	– to +	+	++?	*
Dandelion greens	++	++	+	++
Dasheens	+	+	+	*
Dates	+	++	–	+
Eggs	+++	+ to ++	– ?	+++
Egg white	–	–	– ?	++
Egg yolk	+++	++	– ?	+++
Eggplant	+	+	+	*
Endive	++	*	+	*
Escarole	+++	*	+	++
Figs	+	*	+ to –	*
Filberts	*	++	*	++
Fish, fat	+	+	*	*
Fish, lean	– to +	+	*	*
Flour, white	–	– to +	–	– to +
Flour, whole wheat	+	+++	–	+
Glucose	–	–	–	–
Grains, whole, dry	+	++	–	+
Grains, sprouted	+	++	++	*
Grapefruit (or juice, fresh or canned)	+	++	+++	++
Grapes	+	+	+ to –	+
Grape juice	–	+ to –	–	– to +
Ham	– to +	++	–	++
Heart	+	++	+ ?	+++
Hickory nuts	*	++	*	++
Honey	–	–	–	–
Horse fat	+	–	–	–
Ice cream (genuine)	++	++	+ ?	+++
Kale	+++	+	++	+++
Kidney	++	++	+ ?	+++
Kohlrabi	*	+	+	*
Lard	– to +	–	–	–
Legumes, sprouted	*	++ ?	++	*
Lemon juice	+	++	+++	++
Lemon juice, dried	?	++	+++	++
Lettuce	+ to ++	++	++	++
Limes (or juice)	–	*	++	*

Food	Vitamin A	Vitamin B	Vitamin C	Vitamin G
Liver	++ to +++	++	+	+++
Malt, green	+	++ ?	++	*
Mangoes	+++	++	+++	++
Margarine	− to ++	−	−	−
Milk (whole)	+++	++	+ variable	+++
Milk, "scalded"	+++	++	+ variable	+++
Milk, condensed	+++	++	+ variable	+++
Milk, evaporated	+++	++	− ?	+++
Milk, dried, whole	+++	++	+ variable	+++
Milk, dried, skim	+	++	+ variable	+++
Milk, fresh, skim	+	++	+ variable	+++
Millet	+	++	*	+
Molasses	−	+	−	*
Mutton	− to +	++	*	+
Mutton fat	+	−	−	*
Oatmeal	− to +	++	−	+
Okra	++	++	*	*
Oleo oil	+	−	−	−
Olive oil	− to +	−	−	−
Onions, raw	− to +	+	++	+
Onions, cooked	− to +	+	+	+
Orange (or juice)	+	++	+++	++
Orange peel	+	+	++	*
Oysters	++	++	+	++
Palm oil	+	−	−	−
Parsley	+++	++	+++	*
Parsnips	− to +	++	*	*
Peaches, raw	+ to ++	+ to ++	++	*
Peanuts	+	++	*	+
Peanut butter	+	++	*	+
Peanut oil	?	−	−	*
Pears	*	++	+	++
Peas, young, green	++	++	+++	+
Peas, dry	+	++	?	+
Peas, sprouted	+	++ ?	++	*
Pecans	+	++	*	*
Peppers, green	++	++	+++	*
Pig kidney fat	++	−	−	−
Pimientos	+++	*	+++	*
Pine nuts	+	+	*	*
Pineapple, fresh, raw	+	++	++	+

Food	Vitamin A	Vitamin B	Vitamin C	Vitamin G
Pineapple, canned	+	++	++ ?	+
Pork	– to +	++	–	++
Potatoes, white	+	++	++	++
Prunes	++	++	–	+
Pumpkin	++	+	+	*
Radish	– to +	++	++	*
Raisins	–	+	–	*
Raspberries	++	+	+++	*
Rhubarb	*	*	+	*
Rice ("polished"), white	–	–	–	–
Rice, whole grain or brown	+	++	–	+
Roe, fish	++	++	?	*
Romaine	++	++	*	*
Rutabaga	– to +	++	+++ ?	*
Rye, whole	+	++	–	+
Salmon, canned	+	*	*	++
Sauerkraut	+	+	+ to ++	*
Shrimp	+	*	*	*
Spinach	+++	+	++	+++
Squash, Hubbard	++	*	*	*
Starch	–	–	–	–
Strawberries	+	+	+++	*
Sugar	–	–	–	–
Swede	*	++	+++ ?	*
Sweetbreads	+	+	*	*
Sweetpotatoes	+++	++	++	*
Tomato, raw or canned	++	++	+++	++
Turnip, white	– to +	++	++	++
Turnip greens	+++	++	+++	++
Veal	– to +	+ ?	*	++
Walnuts	+	++	*	*
Watercress	+++	++	+++	++
Watermelon	+	+	+++	+
Whale oil	++	–	–	–
Wheat bran	+	++	–	+
Wheat embryo	++	+++	–	++
Wheat endosperm	–	+ ?	–	+ ?
Wheat flour, white	–	+ ?	–	+ ?
Wheat middlings	*	++ ?	–	+
Wheat, whole	+	++	–	+
Yeast	–	+++	–	+++
Yeast extract	–	+++	–	+++

APPENDIX V.

*SCORE CARD FOR DAIRY FARMS AND CATTLE

I.

Farm of .... Location ....
Application or Permit Number .... Consignee ....
Date inspected .... Time ...... Signature of person interviewed ....

	Score Perfect	Score Allowed
(A) STABLE AND YARD		
1. **Stable**: Site, including the yard, well drained, clean, and free from contaminating surroundings	3	
(Manure stored less than 50 feet from stable, 0).		
2. Construction of stable: Tight, sound floor, proper gutter, tie and manger	3	
Smooth, tight walls and ceiling	2	
3. Light: Four square feet glass per stall, adequate artificial light for milking	2	
(Three square feet, allow 1; two square feet, allow ½.)		
4. Ventilation: Automatic system, in proper working order	1	
Adjustable windows, 1		
Cubic feet air space per cow:		
Over 600 cubic feet	2	
500 cubic feet to 600 cubic feet allow 1.		
Stable air	2	
5. Cleanliness:		
Floor	1	
Wall, ceiling ledges	1	
Mangers and partitions	1	
Windows	1	
Bedding	1	
(B) MILK HOUSE		
1. Site: Convenient, free from contaminating surroundings, with separate wash room	1	
Total forwarded	21	

*(Courtesy of the Health Department of the District of Columbia).

	Score Perfect	Score Allowed
Total forwarded	21	
2. Construction: Walls, floors, and ceiling	1	
3. Cleanliness of milk room, including freedom from flies	2	
4. Light, ventilation, and screens	1	
5. Facilities for storage of milk	1	
(C) UTENSILS		
1. Small-top milking pail	10	
2. Construction and cleanliness of all utensils	5	
3. Sterilizing by steam Boiling water, 3.	15	
(D) WATER SUPPLY		
1. Water for cleansing utensils (Clean, convenient, and sufficient.)	5	
2. Water facilities for cleansing building and equipment and for employees' hands	1	
3. Water supply for cattle	1	
(E) METHOD OF MILKING AND CARE OF MILK		
1. Udders washed with clean water, dried with clean individual towel (Dried with moist cloth, 3.)	5	
2. Each pail of milk removed to dairy immediately after filled	1	
3. Strainer, sanitary cloth used only once	2	
4. Prompt cooling	2	
5. Efficient cooling, below 50° (51° to 55°, 5; 56° to 60°, 1; above 60°, 0.)	10	
6. Storage below 50°F.	5	
7. Transportation iced (Jacketed 2; clean, wet blanket, 1; covered wagons, 1.)	3	
(F) ATTENDANTS		
1. Medical inspection	3	
2. Cleanliness	1	
3. Apparent health	1	
Total forwarded	96	

	Score	
	Perfect	Allowed
Total forwarded	96	
(G) PRIVY		
1. Location	1	
2. Construction	1	
3. Cleanliness	1	
4. Disposal of contents	1	
Total	100	

II.

CATTLE SCORE

Number cattle perfect score, 100. Total possible score ....

DEDUCTIONS ON ACCOUNT OF CATTLE DISEASED, ETC.			
Number cattle	Nature of disease of cattle	Deductions	
		per cow	Total
....	1. Tuberculosis as shown by physical examination or by tuberculin test	100	
....	2. Absence of tuberculin test within 1 year of date of inspection, not to include cattle scored in par. 1	50	
....	3. Inflammatory disease of udder	100	
....	4. Diseases other than or in addition to the above	100	
....	5. Unclean condition of cows, including teats and udders	40	
....	6. Udders and flanks and tail not clipped....	20	
....	7. Undue emaciation of cows or otherwise out of condition	10	

TOTAL DEDUCTION ....

NET SCORE ....

Remarks ....

....

....

....

Signature of Dairy Farm Inspector ....

*PASTEURIZATION PLANT SCORE CARD

I.

Owner or manager ....Trade name ....
Street and No. ....Permit No. ....
Person interviewed ....Date of inspection ....
Gallons sold daily: .... Milk; .... Cream; .... Buttermilk

Item No.	Score Perfect	Score Allowed
(1) *Processing*	1	
Separate processing rooms.		
(2) *Floors*	1	
Smooth finish, no pools, wall joints and floor surface impervious, trapped drain, clean and free of materials and equipment not in routine use.		
(3) *Walls and ceilings*	1	
Smooth, washable, light-colored finish, clean and in good repair.		
(4) *Doors and windows*	1	
In fly season (outer openings with effective screens in good repair) or fly-repellent fans or flaps, self-closing doors.		
(5) *Lighting*	1	
Adequate artificial light evenly distributed, window area 10 per cent of the floor area.		
(6) *Ventilation*	1	
Ample to prevent undue condensation.		
(7) *Water supply*	1	
Sufficient outlets, adequate, safe. Hand-washing facilities, convenient hot water, soap and sanitary towels provided.		
(8) *Toilet facilities*	1	
Comply with plumbing code, good repair, clean, ventilated vestibuled, self-closing doors free of flies.		
(9) *Disposal of wastes*	1	
Public sewer or an approved waste-disposal system.		
(10) *Storage of containers*	1	
Inverted in crates or in racks in a clean place, free from flies, splash, or dust.		
(11) *Handling of containers*	1	
No handling of surfaces to which milk is exposed.		
Total forwarded	11	

*(Courtesy of the Health Department of the District of Columbia).

	Score: Perfect	Score: Allowed
Total forwarded	11	
(12) *Storage of caps, etc.*	1	
Caps purchased in tubes, parchment paper for cans in cartons, kept in a clean place, first cap and paper discarded.		
(13) *Protection from contamination*	5	
Raw milk not unloaded into pasteurization room, dump vat covered and above the level of the floor, pasteurized milk not in contact with unsterilized raw milk equipment, no raw milk bypasses around pasteurizer, coolers properly covered, no direct openings to stables or living quarters. No woven-wire strainers.		
(14) *Equipment—Construction and repair*	10	
A—Milk piping: Sanitary type easily cleanable; size and length; no open seams; smooth, uncorroded surfaces; sanitary fittings; interior surfaces accessible for inspection. Kept in good repair. Pressure-type seats on submerged thermometer openings.		
B—Clarifier ( ), filter ( ).		
C—Washing machines: Case type ( ), soaker type with brushes ( ), soaker type without brushes ( ), milk crate washer ( ).		
(15) *Cleaning and bacterial treatment of containers and apparatus*	10	
Containers shall be thoroughly cleansed and treated after each usage to reduce bacterial count, assembled apparatus treated once daily, immediately before run, with steam flow 200°F. or chlorine solution flow at 50 parts per million at outlet for 5 minutes.		
(16) *Indicating and recording thermometers*	5	
Each holder shall be equipped with an approved indicating and recording thermometer.		
(17) *Preheating holder*	5	
Holders not used as heaters, preheated to pasteurization temperature immediately before use.		
(18) *Pasteurization*	10	
Charts on holders must show milk held at 142°F. for 30 minutes. Milk in all vats and pockets agitated throughout holding period. Leak protector inlet and outlet valves. Milk foam in pasteurizer must be heated 5°F. above pasteurizing temperature with an approved device. Pasteurizer covers, tight fitting and		
Total forwarded	57	

	Score: Perfect	Score: Allowed
Total forwarded	57	
kept closed.		
(19) *Cooling*	10	
All raw milk pasteurized or cooled to 50°F. or below, within 2 hours after receipt and held at that temperature until delivered.		
(20) *Bottling*	3	
Automatic bottler: Simple design; smooth, noncorrodible material; properly covered; readily cleanable; float adjustable without lifting cover; filler pipe equipped with condensation diverting apron; infeed conveyor provided with overhead shields.		
(21) *Storage of milk and cream*	5	
All milk and cream stored on premises.		
(22) *Overflow milk*	1	
Overflow milk discarded.		
(23) *Capping*	10	
Automatic capper, imperfectly capped bottles dumped. Cover all caps used. (Disc caps 5.)		
(24) *Personnel—Health*	10	
Medical examination and test required of all milk handlers. Rejected persons not employed.		
(25) *Personnel—cleanliness*	2	
Clean outer garments, washable for inside employees; hands clean.		
(26) *Vehicles*	1	
Clean, covered, no contaminating substances transported. Properly lettered with the name, address, and permit number of said dealer.		
(27) *Premises*	1	
Surroundings kept neat and clean.		
Total Score	100	
Deductions for exceptionally bad conditions.		
....	....	....
....	....	....
....	....	....
Net Score		

APPENDIX VI.

INSPECTION OF DAIRY FARM

____

Date of Inspection.

I.

Operator .... Address....................

Location ....

Number of dairy cattle .... Number milked ....

Number of gallons of milk produced daily ....

Number of employees who are milk handlers ....

Employees physically examined by ....

Name of civilian physician or Med. Off.

Disposition of milk ....

(Direct to consumer or to milk plant)

Number of gallons delivered for consumption by troops: Direct ....

Through milk plant ....

(Name and address of milk plant)

II.

CATTLE, FACILITIES AND EQUIPMENT, METHODS AND PERSONNEL

Note: The total number of points awarded under each item may be a plus or minus quantity.

Item No.	Item	Perfect	Score Deductions: Prescribed	Score Deductions: Deducted	Awarded
1.	Site of buildings and the ground accessible to cattle	2			
	a. Poor drainage		1		
	b. Contamination other than manure		0.5		
	c. Manure within 50 feet of stable or milk house		1		
	d. Manure within 100 feet of stable or milk house		0.5		
	Sub Total	2			
2.	Stable (structural and sanitary features)				
	a. Construction of stables	4			
	(1) Loose or rough floors		0.5		
	(2) Ceilings or walls permeable for dust		1.0		
	(3) Gutters				
	(a) Absence of gutters		2.0		
	(b) Improperly placed		0.5		
	(c) Poorly drained		0.5		
	(4) Mangers and stanchions				
	(a) Mangers difficult to clean		0.5		
	(b) Poorly constructed		0.5		
	(5) Lighting (at least 4 sq. ft. of glass per cow, properly distributed, or adequate artificial light)	2			
	(a) For each sq. ft. of glass less than 4 feet per cow		1.0		
	(b) Poor distribution of window area		0.5		
	(c) Inadequate artificial light		0.5		
	Sub Total	6			
	(6) Ventilation (more than 500 and less than 1000 cu. ft. of air space per cow with suitable ventilation)	3			
	(a) Less than 500 and more than 400 cu. ft. of air space per cow		0.5		
	(b) Less than 400 and more than 300 cu. ft. of air space per cow		1.0		

(c) Less than 300 cu. ft. of air space per cow		2.0		
(d) Absence of, or inadequate exhaust ducts		0.5		
(e) Nonadjustable windows		1.0		
Sub Total	3			
b. Sanitation of stables	1			
(1) Interior of stables				
(a) Manure and debris on floor		1.0		
(b) Walls not painted or whitewashed		0.5		
(c) Walls dirty		0.5		
(d) Ceilings and ledges dirty		0.5		
(e) Gutters poorly cleaned		0.5		
(f) Mangers containing old feed		0.5		
(g) Bedding dirty, dusty or mouldy		0.5		
(h) Absence of bedding		0.5		
(i) Insufficient bedding		0.5		
(j) Dust in stable air		1.0		
(k) Abnormal odors		0.5		
Sub Total	1			
(2) Barnyard (clean and well drained)	2			
(a) Dirty barnyard		1.0		
(b) Poorly drained barnyard		1.0		
Sub Total	2			
(3) Removal of manure (daily to a distance of 100 feet or more)	4			
(a) At regular intervals of more than one day but less than one week		1.0		
(b) At greater than one week intervals		3.0		
(c) To a distance of less than 50 ft.		2.0		
(d) To a distance of more than 50 but less than 100 ft.		1.0		
Sub Total	4			
3. Health of cattle (exclusive of conditions noted in III below)	8			
a. Apparently healthy but not tuberculin tested		4.0		
b. Tuberculin tested within one year and reactors removed but not accredited		2.0		
c. No history of infectious abortion, but no blood serum tests		2.0		
d. Generally poor condition but no evidence of disease		2.0		
Sub Total	8			
4. Care of cattle				
a. Feed	2			
(1) Unwholesome but edible		1.0		

(2) Dusty and mouldy		1.0		
(3) Insufficient in quantity		1.0		
Sub Total	2			
b. Water (clean, fresh and ample in quantity)	2			
(1) Turbid (more than 100 ppm. estimated)		0.5		
(2) Stagnant (odors or algae)		1.0		
(3) Insufficient in quantity		0.5		
(4) Not supplied at proper intervals		0.5		
(5) Not readily accessible		0.5		
Sub Total	2			
c. Grooming (flanks, to include legs and tail, free from manure and long hairs. Udders and teats washed and wiped dry prior to each milking)	3			
(1) Flanks and udders improperly cleaned		2.0		
(2) Udders and teats wiped with moist cloths—not washed		1.0		
(3) Long hairs on flanks and udder		1.0		
Sub Total	3			
d. Exercise (at least 2 hours daily)	1			
(1) No exercise		1.0		
(2) Exercise at irregular intervals but daily or less than 2 hours daily		0.5		
(3) Exercise in dirty yard		0.5		
Sub Total	1			
5. Milking process (by machines with immediate removal of milk to milk house)	12			
a. Milking by hand		4.0		
b. Delay in removing to milk house		4.0		
c. Transfer of milk to other containers within stable		4.0		
d. Failure to use small top pail		2.0		
e. Dirty milking pails		4.0		
f. Dirty milk stools		1.0		
g. Failure of milkers to wash and dry hands before milking each animal		4.0		
Sub Total	12			
6. Milk house or milk room				
a. Location (separate from stable—free from sources of contamination)	2			
(1) Opening into stable		1.0		
(2) Sources of contamination (manure, etc.)				
(a) Within 50 feet		1.0		
(b) Within 100 feet		0.5		
Sub Total	2			

b. Floors (concrete or metal, impervious and smooth)	1			
(1) Pervious		1.0		
(2) Wooden		1.0		
(3) Inadequate floor space		1.0		
Sub Total	1			
c. Walls and ceilings (impervious and easy to clean with water or steam)	1			
(1) Pervious		1.0		
(2) Rough and difficult to clean		1.0		
Sub Total	1			
d. Ventilation (sufficient to prevent abnormal odors and closeness)	1			
(1) Inadequate ventilation system		1.0		
Sub Total	1			
e. Lighting (windows properly distributed. Adequate artificial light)	1			
(1) Improper distribution of windows		0.5		
(2) Insufficient window area		1.0		
(3) Inadequate artificial lighting		0.5		
Sub Total	1			
f. Screening (properly installed and maintained. Self closing screen doors)	2			
(1) No screening		2.0		
(2) Defects in screen which can be repaired		1.0		
(3) New screening required		1.0		
Sub Total	2			
g. Handling of milk (properly strained and cooled at once to less than 50 degrees F.)	10			
(1) Not strained		2.0		
(2) Strained through dirty strainer or straining cloth		3.0		
(3) Cooled to between 50 and 55 degrees F.		2.0		
(4) Cooled to between 55 and 60 degrees F.		4.0		
(5) Not cooled or not to 60 degrees F.		10.0		
Sub Total	10			
h. Care of utensils (thorough washing and sterilization with steam)	10			
(1) Not washed with washing compound		4.0		
(2) Not sterilized		6.0		
(3) Sterilized with chlorine instead of steam		2.0		
(4) Cooler not sterilized		4.0		
(5) Milk cans not sterilized		2.0		
(6) Milk pails not sterilized		4.0		

Sub Total	10			
1. Care of milk house (daily scrubbing of floor and walls, cleaning of ceiling and painted walls, absence of flies and dust)	7			
(1) Failure to scrub floor and clean ceiling daily		5.0		
(2) Dirty floor, wall or ceiling		2.0		
(3) Presence of house flies		2.0		
(4) Presence of dust in air		2.0		
(5) Abnormal odors or closeness of air		2.0		
Sub Total	7			
7. Personnel (physically examined on employment and every 6 months thereafter: daily observation and exclusion of sick)	10			
a. Physical examination				
(1) On employment but not thereafter		3.0		
(2) On employment and at periods of more than 6 but not more than 12 months thereafter		1.0		
(3) No physical examination		5.0		
b. Only casual observation from time to time (not daily)		1.0		
c. Only observation on complaint of illness by employee		2.0		
d. Not observed		3.0		
e. Failure to relieve from work for colds, fever, or diarrhea not incapacitating		4.0		
Sub Total	10			
8. Cleanliness of personnel (clean person and clothing; training in rules of cleanliness)	5			
a. Dirty hands or finger nails		2.0		
b. Soiled clothing		1.0		
c. Failure to wash hands each time after visiting toilet		2.0		
d. Ignorance of employees relative to necessity for cleanliness and methods to be used		3.0		
Sub Total	5			
e. Facilities for personnel (lavatory with ample supply of water, soap and towels; suitable toilet facilities; dust proof storage space for working clothes)	4			
(1) Insufficient water		1.0		
(2) Nonpotable water supply		2.0		
(3) Inadequate lavatory facilities		1.0		
(4) Inadequate toilet facilities		2.0		
(5) Lack of, or unsuitable storage space for working clothes		1.0		
Sub Total	4			
Total	100			

III.

CONDITIONS WHICH RENDER THE DAIRY UNSUITABLE AS A SOURCE OF SUPPLY REGARDLESS OF THE SCORE ATTAINED.

---

1. Health of the cattle.
   a. Tuberculosis, as diagnosed by physical examination or tuberculin tests.
      Remarks ....
      ....
   b. Infectious abortion, as diagnosed by history or blood serum tests.
      Remarks ....
      ....
   c. Inflammatory disease of the udder.
      Remarks ....
      ....
   d. Other diseases or conditions which would render the milk dangerous to the health of the troops.
      Remarks ....
      ....

2. Quality of the milk.
   a. Bacterial count of more than 200,000 per c.c. prior to pasteurization.
      Remarks ....
      ....
   b. Sediment.
      a. Milk classed as slightly dirty by sediment test (2.5 mgms. per pint).
      Remarks ....
      ....

3. Health of personnel.
   a. Presence of cases or carriers of communicable diseases among milk handlers.
      Remarks ....
      ....
      ....

Recommendations: ....

Signature ....

....

Rank and Organization.

INSPECTION OF MILK PLANT

Date of Inspection..................

I.

Operator ....
Address ....
Trade name .... Permit number ....
Dairies from which milk is obtained ....
....
....
Gallons sold daily: Pasteurized milk .... Raw milk ....
Milk products sold: Daily amounts, Butter ....
Cream .... Cheese .... Ice Cream ....
Other ....
Gallons of milk delivered for consumption by troops ....
Remarks ....
....
....
....

II.

FACILITIES AND EQUIPMENT, METHODS AND PERSONNEL

Item No.	Item	Perfect	Score Deductions		Awarded
			Prescribed	Deducted	
1.	Location (dust free surroundings, absence of fly breeding places, open privies, cesspools and other contamination)	2			
	a. Dusty roads or ground in immediate vicinity		0.5		
	b. Fly breeding places, open privies or cesspools				
	(1) Within 100 yards		2.0		
	(2) Within 200 yards		1.5		
	(3) Within 500 yards		1.0		
	c. Other sources of contamination within 500 yards		0.5		
2.	Construction (floor, walls and ceiling impervious, smooth and without defects. Proper drainage of floors. Adequate plumbing)	3			

a. Pervious floors (wood or brick)		2.0		
b. Wooden walls or ceilings		2.0		
c. Improperly drained floors		1.0		
e. Rough or defective floors, walls or ceilings		1.0		
Sub Total	5			
3. Screening (properly installed and maintained. Self closing screen doors)	1			
a. No screening		1.0		
b. Defects in screen which can be repaired		0.5		
c. New screening required		1.0		
Sub Total	1			
4. Ventilation (vacuum system—exhaust fans and window or register inlets; windows only but ample)	1			
a. Insufficient		0.5		
b. Abnormal odors		1.0		
Sub Total	1			
5. Lighting (window glass area 15% of floor space and properly distributed. Adequate artificial lighting)	1			
a. Window glass area less than 15% but more than 10%		0.5		
b. Window glass area less than 10%		1.0		
c. Window glass area improperly distributed		0.5		
d. Inadequate artificial lighting		0.5		
Sub Total	1			
6. Pasteurizing room (separate from all others)	3			
a. Combined with:				
(1) Sales room		0.5		
(2) Receiving room		0.5		
(3) Refrigeration room		0.5		
(4) Boiler room		0.5		
(5) Handling room		0.5		
(6) Wash room		0.5		
b. Connected with or opening into:				
(1) Laundry		0.5		
(2) Toilet		1.0		
Sub Total	3			
7. Receiving of milk (immediate dumping with facilities for cold storage if not sent direct to pasteurizer)	1			
a. Delay in dumping		0.5		
b. Failure to store in cooled tank or pasteurize immediately		1.0		
c. Weigh tank not steam sterilized after use		1.0		
d. Storage tank not steam sterilized after use		1.0		
Sub Total	1			

8. Pasteurization equipment (suitable holders, automatic temperature regulators and recorders and leak protector valves)	10			
a. Continuous holder of suitable type		2.0		
b. Automatic temperature regulation without recording		4.0		
c. Automatic temperature recording with manual regulation		4.0		
d. Manual temperature regulation and recording		6.0		
e. Absence of leak protector valves		3.0		
f. Piping or construction that will cause cold pockets or cold foam		5.0		
Sub Total	10			
9. Cooling equipment (cooler of suitable type and adequate size. Brine or ammonia as cooling medium)	5			
a. Cooler of inadequate size		3.0		
b. Ice water as cooling medium throughout		2.0		
Sub Total	5			
10. Cleansing and sterilization of pasteurizing and cooling equipment (cleaned with washing powder solution, rinsed and sterilized after use. Cooler and effluent piping re-sterilized immediately before using. All joints, cross connections and valves taken apart for cleaning and sterilizing	10			
a. Delay in cleaning and sterilizing		2.0		
b. Inadequate cleaning or sterilizing		3.0		
c. Failure to take all piping and valves apart		3.0		
d. Lack of protection from recontamination		4.0		
e. Failure to re-sterilize cooler and effluent piping before use		1.0		
Sub Total	10			
11. Method of pasteurizing and cooling (holding method. Adequate control of pasteurization and cooling)	14			
a. Temperature less than 145 but not less than 142° F.		4.0		
b. Portion of the milk not held for the full pasteurizing period		7.0		
c. Excessive formation of cold foam		5.0		
d. Thermometers not checked routinely at definite intervals		4.0		
e. Continuous holders not tested for rate of flow		6.0		
f. Milk pumped after leaving pasteurizer		1.0		
g. Milk not cooled to less than 50°F.		10.0		
Sub Total	14			
12. Clarification (clarified before pasteurization in centrifugal clarifier)	3			
a. Clarified after pasteurization		1.0		
b. Clarified by filtration		1.0		

c. Clarifier not properly cleaned and steam sterilized after use		2.0		
Sub Total	3			
13. Bottling and capping (automatic filling and capping)	3			
a. Hand filling and capping		2.0		
b. Automatic filling and hand capping		1.0		
c. Apparatus not properly cleaned and sterilized after use		3.0		
Sub Total	3			
14. Bottle washing (power washer and adequate sterilization. Washed bottles inspected)	6			
a. Power washer not properly operated		5.0		
b. Hand washing and steam sterilization		3.0		
c. Hand washing and chlorine sterilization		2.0		
d. Washed bottles not inspected		2.0		
e. Washed bottles not sterile		5.0		
Sub Total	6			
15. Milk pumps and pipes (easily disconnected for cleaning. Sterilized with steam after use. Inner surface smooth)	3			
a. Difficult to take completely apart		1.0		
b. Not taken apart for cleaning and sterilization		2.0		
c. Not adequately cleaned and sterilized after use		3.0		
d. Inner surface rough or defective		1.0		
Sub Total	3			
16. Cleansing of milk cans (cleaned with washing powder solution and sterilized)	2			
a. Cleaned but not properly sterilized		1.0		
b. Not cleaned and not sterilized		2.0		
c. Covers not sterilized		1.0		
Sub Total	2			
17. Storage of pasteurizied milk (at a temperature of less than 50 degrees F. immediately after bottling or after cooling if not bottled. Storage rooms well ventilated)	5			
a. Temperature between 50° and 55°F.		3.0		
b. Temperature between 55° and 60°F.		4.0		
c. Temperature above 60° F.		5.0		
d. Poor ventilation with abnormal odors		2.0		
Sub Total	5			
18. Arrangement of equipment (all apparatus easily accessible for cleaning. Not more than one pump—remainder of flow by gravity)	4			
a. Any apparatus or part of apparatus difficult of access for cleaning or sterilizing		3.0		

b. More than one pump		1.0		
Sub Total	4			
19. Delivery to consumer (delivery within 24 hours after pasteurization. Transported in covered vehicle. Cooling during transportation in warm weather)	4			
a. Delivered in less than 36 but more than 24 hours after pasteurization		1.0		
b. Not iced in warm weather		2.0		
c. Vehicle not covered		3.0		
d. Delivered after 36 hours		4.0		
Sub Total	4			
20. Personnel (physically examined on employment and every 6 months thereafter; daily observation and exclusion of sick)	10			
a. Physical examination				
(1) On employment but not thereafter		3.0		
(2) On employment and at periods of more than 6 but not more than 12 months thereafter		1.0		
(3) No physical examination		5.0		
b. Only casual observation from time to time (not daily)		1.0		
c. Only observation on complaint of illness of employee		2.0		
d. Not observed		3.0		
e. Failure to relieve from work for colds, fever or diarrhea not incapacitating		4.0		
Sub Total	10			
21. Cleanliness of personnel. (Clean person and clothing; training in rules of cleanliness)	5			
a. Dirty hands or finger nails		2.0		
b. Soiled clothing		1.0		
c. Failure to wash hands each time after visiting toilet		2.0		
d. Ignorance of employees relative to necessity for cleanliness and methods to be used		3.0		
Sub Total	5			
22. Facilities for personnel. (Lavatory with ample supply of water, soap and towels; suitable toilet facilities; dustproof storage space for working clothes)	4			
a. Insufficient water		1.0		
b. Nonpotable water supply		2.0		
c. Inadequate lavatory facilities		1.0		
d. Inadequate toilet facilities		2.0		
e. Lack of, or unsuitable storage space for working clothes		1.0		
Sub Total	4			
Total	100			

III.

CONDITIONS WHICH WOULD RENDER PASTEURIZED MILK UNSUITABLE FOR CONSUMPTION BY TROOPS

1. Quality of the milk.
   a. Bacterial count of more than 200,000 per c.c. prior to pasteurization or more than 30,000 at any time after pasteurization.
   Remarks ....
   ....

2. Sediment.
   a. Milk containing 2.5 mgms. of dirt per pint before or 1.25 mgms. per pint after pasteurization.
   Remarks ....
   ....

3. Health of milk plant personnel.
   a. Presence of cases or carriers of disease transmissible by milk.
   Remarks ....
   ....

4. Defects in operation of the plant.
   a. Failure to hold all the milk at a pasteurizing temperature for a period of 30 minutes.
   Remarks ....
   ....

5. Recontamination after pasteurization.
   Remarks ....
   ....

Recommendations: ....
....
....

Signature ....

....
Rank and Organization.

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